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Research article

GROWTH PERFORMANCE AND STAND STRUCTURE OF SOME *ACACIA* SPP. IN SOUTH WESTERN SAUDI ARABIA

Ibrahim Mohamed Aref[1] and Hashim Ali El Atta[*1]

[1]Department of Plant Production, College of Food and Agricultural Sciences, King Saud University, Riyadh Posta Code: 11451, P.O. Box 2460, Saudi Arabia.

ABSTRACT: Naturally growing *Acacia* spp. occur mostly as woodlots in some parts of Saudi Arabia. They are extremely important types of vegetation in a country with a very small vegetation cover and huge areas of deserts. The present study was carried out in five locations in Al Baha Region (semi-arid) in south western Saudi Arabia. The objective of the study was to assess the growth performance and stand structure of the natural cover of *Acacia* spp. in these locations. Such information is very essential for inference on the types of products that can be expected from forest utilization, it is central to growth and yield projection, and crucial for ecological assessment. Growth parameters measured were DBH (diameter at breast height, 1.3m), total height, basal area/ha, volume/ha, crown coverage relative to the total land area, stocking density and regeneration capacity. The results revealed that most of these species occurred as woodlots and few as forests. Generally, the stocking density and regeneration were low probably due to illicit felling for fuel wood and grazing. Tree heights were below the average perhaps due to the low stocking density and increased natural spacing between trees. Large trees were extremely rare; however the remaining stumps on the forest floor suggested that they were mostly felled down probably for fuel wood or construction purposes. Currently *Acacia* spp. in the study locations may provide very important environmental roles and non-wood products rather than provision of wood products. These forests and woodlots require immediate intervention and protection to attain sustainability.
Keywords: Growth, *Acacia Spp*. South Western, Saudi Arabia

INTRODUCTION

The land area of Saudi Arabia is approximately 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. The forest cover in Saudi Arabia was estimated at 2% or less of the total land area [1] [2]. 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 [3]. *Acacia* spp. 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 [4]. 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 [5]. 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. Measurement of the structural attributes of vegetation is an essential component of forest inventory. Currently, most forest inventories involve traditional methods that require intensive field efforts.

The sampling designs of such field visits are dependent on accuracy and precise specifications, area coverage, and the budget of the inventory. Sampling strategy is an integral part of this method, since covering vast forest tracts is challenging [6] [7]. Since the assessment of the total population is often considered too expensive or even impossible for inventories of large areas, forest characteristics are most commonly estimated by various sampling methods [8]. A common way to measure trees is to record `diameter at breast height', or DBH. DBH is then used to calculate tree growth, basal area, and biomass [9].
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. Forest management requires precise knowledge of forest parameters on which to base important management decisions. On top of the simple population parameters like heights, mean diameters, number of individuals per hectare etc., the stand table, i.e. the diameter distribution, is important. It allows inference on the types of products that can be expected from forest utilization, it is central to growth and yield projection, and crucial for ecological assessment [10]. The current study was undertaken in an attempt to evaluate the growth performance and stand structure of the naturally growing *Acacia* spp. in Al Baha Region (south-west Saudi Arabia).

MATERIALS AND METHODS

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 outside the circle were marked using a paint sprayer. Depending on the species distribution and density, a number of sample plots were laid out in the study locations (Table 1) in Al Baha region. The following parameters were measured inside each sample plot: Tree species, DBH, total height, crown diameter of the tallest, shortest and medium trees was measured using a measuring stick and averaged, and the number of seedlings was counted. The DBH was measured using a caliper and total height was measured using a measuring stick. Based on these measurements the mean DBH/ha, mean total height/ha, basal area and tree volume/ha, crown coverage (%) and the number of seedlings/ha were computed. The DBH distribution curves were drawn for all locations.

Table 1. The study areas in Al Baha Region

Location	Coordinates	Species
Al Ageeg Al Matar	N 1949613 E4134380	*Acacia etbaica*
Al Gimda	N 1949613 E4135280	*A.origena*
Al Mekhwa	N 50530 E4136476	*A.asak*
Kara Al Ageeg	N 1946432 E4137133	*A.tortilis raddiana.* *A.ehrenbergiana* *A.gerrardii*
Wadi Batat	N 1953413 E4137175	*A.tortilis tortilis* *A.ehrenbergiana*

RESULTS AND DISUCUSSION

Measurement of growth parameters

The results of the growth parameters of *Acacia* spp. were summarized in tables 2-9. The variability in growth parameters in sample plots in all locations is very little as indicated by the extremely low values of standard deviations and standard errors. Crown coverage ranged between 7.4 % to 14.8 %.

As such most of locations in Al Baha are considered as forests since they exceeded the 10 % minimum coverage of the crown of the total land area. However, it is apparent that the number of seedlings/ha is relatively low (0-152) probably due to intensive grazing. The only exception is Al Gimda which recorded 410 seedlings/ha. This was indicated by the fact that human settlements are close to the forests. The average total height of *Acacia* trees (3.3-6.5 m) is relatively low and this may be attributed to the wide spacing between trees which reduced competition for light. Acacias, in general, are well known as light demanders. Therefore, if grown at close spacing they grow more in height in search of light which is not the case in the studied locations.

Table 2. Growth parameters of *Acacia etbaica* Al Baha (Al Ageeg-Al Matar Plot 1)

Parameter	N	Range	Mean	S.E.	S.D.	Variance
DBH (cm)	94	23.00	11.16	0.44	4.32	18.70
Total Height (m)	94	5.80	5.39	0.13	1.26	1.61
Basal area (m^2)	94	0.0560	0.01	0.001	0.009	0.00
Volume (m^3)	94	0.1987	0.03	0.003	0.03	0.001
Seedlings/ha	120					
Crown%	13.8					

Table 3. Growth parameters of *Acacia etbaica* (Al Ageeg-Al Matar Plot 2)

Paremeter	N	Range	Mean	S.E.	S.D.	Variance
DBH (cm)	41	73.00	19.98	2.27	14.54	211.656
Total Height (m)	41	5.38	6.14	0.20	1.30	1.691
Basal area (m^2)	41	.4986	0.047	0.01	0.09	0.008
Volume (m^3)	41	1.8328	0.16	.05320	0.34	0.116
Seedlings/ha	0					
Crown %	14					

Table 4. Growth parameters of *Acacia origena* (Al Gimda)

Parameter	N	Range	Mean	S.E.	S.D.	Variance
DBH (cm)	147	23.50	7.81	0.28	3.40	11.593
Total Height (m)	147	6.50	5.50	0.100	1.22	1.489
Basal area (m^2)	147	0.0544	0.005	0.0005	0.006	0.000
Volume (m^3)	147	0.2055	0.016	0.001	0.02	0.000
Seedlings/ha	410					
Crown %	7.4					

Table 5. Growth parameters of *Acacia asak* (Al Mekhwa)

Parameter	N	Range	Mean	S.E.	S.D.	Variance
DBH (cm)	23	29.47	14.167	1.77	8.52	72.607
Total Height (m)	23	6.30	5.9465	0.40	1.94	3.789
Basal area (m^2)	23	.0867	.02120	0.004	.023	.001
Volume (m^3)	23	.3256	.07782	0.019	.095	.009
Seedlings/ha	0					
Crown %	9.5					

Table 6. Growth parameters of *Acacia etbaica* (Kara-Al Ageeg Plot 1)

Parameter	N	Range	Mean	S.E.	S.D.	Variance
DBH (cm)	57	22.00	6.80	0.58	4.40	19.417
Total Height (m)	57	4.40	4.08	0.10	0.77	0.595
Basal area (m^2)	57	0.0484	0.005	0.001	0.008	0.000
Volume (m^3)	57	0.1532	0.011	0.003	0.023	0.001
Seedlings/ha	120					
Crown %	13.5					

Table 7. Growth parameters of *Acacia etbaica* (Kara-Al Ageeg Plot 2)

Parameter	N	Range	Mean	S.E.	S.D.	Variance
DBH (cm)	79	13.00	4.69	0.25	2.25	5.086
Total height (m)	79	3.25	4.11	0.063	0.56	0.322
Basal area (m^2)	79	0.0173	0.002	0.0002	0.002	0.002
Volume (m^3)	79	0.0506	0.004	0.0007	0.006	0.003
Seedlings/ha	80					
Crown %	7.8					

Table 8. Growth parameters of *Acacia ehrenbergiana* & *A. tortilis* (Wadi Batat Plot 1)

Parameter	N	Range	Mean	S.E.	S.D.	Variance
DBH (cm)	86	14.00	6.35	0.36	3.35	11.238
Total Height (m)	86	4.51	4.82	0.10	0.96	0.934
Basal area (m^2)	86	0.0198	0.004	0.0004	0.004	0.0001
Volume (m^3)	86	0.0518	0.011	0.0014	0.013	0.0003
Seedlings/ha	100					
Crown %	14.8					

Table 9. Growth parameters of *Acacia ehrenbergiana* & *A. tortilis* (Wadi-Batat) Plot 2)

Parameter	N	Range	Mean	S.E.	S.D.	Variance
DBH (cm)	115	8.00	5.67	0.17	1.89	3.601
Total Height (m)	115	3.90	4.77	0.07	0.81	0.668
Basal area (m^2)	115	0.0088	0.002	0.0001	0.001	0.0001
Volume (m^3)	115	0.0197	0.006	0.0004	0.004	0.0004
Seedlings/ha	140					
Crown %	24					

Table 10. DBH

Species	**Mean DBH (cm)**
A. asak	14.9 a
A. etbaica	11.2 b
A.origena	7.8 c
A.gerrardii	7.3 cd
A.ehrenbergiana	5.9 ce
A.tortilis raddiana	5.0 ce
A.tortilis tortilis	4.1 f

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

Table 11. Total Height

Species	Mean Total Height (cm)
A. asak	6.1 a
A. origena	5.5 a
A. etbaica	5.3 a
A. tortilis tortilis	4.3 b
A. ehrenbergiana	4.1 b
A. gerrardii	3.6 b
A. tortilis raddiana	4.1 f

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

Table 12. Basal area/ha

Species	Mean Basal Area/0.1 ha
A. asak	0.6 a
A. etbaica	0.1a
A.origena	0.06b
A. gerrardii	0.05b
A.. ehrenbergiana	0.03bc
A. tortilis raddiana	0.02 c
A. tortilis tortilis	0.01c

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

Table 13. Volume/ha

Species	LSMean Basal Area/0.1 ha
A. asak	2.4 a
A. etbaica	0.3b
A.origena	0.2b
A. gerrardii	0.1b
A. ehrenbergiana	0.06
A. tortilis raddiana	0.03c
A. tortilis tortilis	0.03c

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

Comparison of growth parameters between locations and species

The results of the comparison between growth parameters were summarized in tables 13-26. Statistical analysis of data showed significant differences in all growth parameters of all species in various locations in Al Baha (Tables 10-13). The mean DBH was maximum for *A. asak* (14.9 cm), followed by *A. etbaica* (11.2 cm), and least for *A. tortilis* varieties (4.1 to 5.0 cm). Considering total height, *A. asak*, *A. origena* and *A. etbaica* reroded the maximum height (5.3-6.1m), whereas the least total height was recorded for the remaining species (3.6-4.1 m) and these differences were significant. Similarly, *A. asak* recorded the maximum mean basal area/ha (0. 6 m^2), followed by *A. etbaica* (0.1 m^2), whereas *A. tortilis* (both varieties) recorded the least basal area (0.01-0.03 m^2), and these differences were significant. Regarding the mean volume/ha, again *A. asak* had the highest volume (2.4 m^3) and *A. tortilis* (both varieties) recorded the least volume (0.03 m^3). It has long been recognized that the most straightforward approach to sampling, enumerating and measuring all the trees on sample strips or plots [11]. The most commonly used variable probability technique in forestry is horizontal point sampling (HPS), also known as variable-radius plot sampling, Bitterlich sampling, angle-count sampling, or prism cruising [11].

Basal area of a stand or tract is most useful as a first step in estimation of volume. Basal area can be used as a measure of stand density, but that use derives historically from the basal area:volume relationship, and practically from ease of measurement, rather than from any expectation of a biological or ecological functional relationship [12]. Ducey and Valentine [13] suggested that the method of sampling for economic value might be used to estimate certain stand density measures from a simple tree count. The basal area of a tree, is proportional to diameter at breast height squared (DBH^2) [14] [15]. In forestry and forest ecology, it is nearly always necessary to sample the population that is of interest in support of a particular management decision or scientific investigation. Unless the area in question is only a few hundred m2, it is usually impractical to enumerate and measure all of the trees within that area.

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. 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 [5]. A high q coefficient would mean that small trees occupy much growing space although they do not produce much economic return [16]. Therefore, a low q ratio, at least within small diameter classes, may lead to better economic results by yielding a higher number of large trees. The distribution may also resemble a rotated sigmoid or bi-modal curve [17]. Stands with a reverse J-shaped diameter distribution have been the most prevalent [23] [24]. This kind of stand structure seems to have been a result of natural disturbances and dynamics of forests. However, the reverse J-shaped curve is not the only applicable model for describing virgin uneven-sized forests [17]. Growing stock volume is a key attribute of inventory by compartments. All compartments need to be visited in the field, and the typical problem is the disparity between the required amount of fieldwork and available resources. In countries characterized by high labour costs, the assessment of growing stock volume at compartment level may be so expensive as to jeopardize management planning [18]. In unmanaged forests, the structures of tree populations often vary considerably, even among stands of the same age (successional stage) and habitat class (forest stand type) [19]. The shape of a tree size distribution, conventionally described as a tree breast height diameter distribution, can be, for example, unimodal, multimodal, decreasing or irregular [10]. Unimodal tree diameter distributions may develop, in particular, if the succession starts after a stand replacing disturbance, and regeneration occurs fairly rapidly. However, often in a disturbance event only a portion of the trees die, and the surviving trees remain as part of the living structure of the stand [20] [21] [22]. This obviously leads to increased variability in tree sizes, and the development of multimodal, decreasing or irregular tree diameter distributions.

CONCLUSIONS

The growth performance and stand structure of the naturally growing *Acacia* spp. in Al Baha Region varied with location and tree species. They were mostly woodlots and to a lesser extent forest stands bases on the average DBH, total height and land area occupied by trees. Human intervention in the form of illicit felling and grazing of animals has been clearly indicated by the relatively low stocking density of trees and seedlings per unit area and the low basal area and volume of wood/ha. Such locations require immediate intervention by planting of seedlings and fencing to enrich these woodlots.

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