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Gum Talha from *Acacia seyal* Del. Variety Seyal in South Kordofan, Sudan

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ABSTRACT
The present study was carried out in Umfakarin natural forest reserve, South Kordofan, Sudan. The main objective was to investigate the possibility of managing *Acacia seyal* Del. variety *seyal* (Bernan) for the production of gum talha (gum obtained from *Acacia seyal*). In this investigation, three stand densities, namely dense, medium and slight, were distinguished based on number of trees per hectare. A total of 482 target trees, covering variable ranges (9-11.5, 13.5-16, 18-20.5 and above 21 cm) of diameter at the base (0.25 m height) were selected for gum tapping experiment. Diameter at breast height of each target tree was measured. Target trees were exposed to tapping, on the first of October, fifteenth of October and first of November, using local tools (*sonki* and *makmak*) in addition to untapped trees used as control. The initial collection of gum was completed fifteen days after tapping while the subsequent (7-9 picks) were done in an interval of fifteen days. Gum yielded by each target tree per season was obtained by summing up the gum samples collected from all pickings. Gum production per unit area in each stand density was also determined. Regression tree model and regression analysis under univariate general linear model were used for analysis of the data obtained. Factors affecting gum production were identified. With exception to stand density, findings of the regression tree model revealed that the diameter at breast height, date and tool of tapping are the most important variables influencing gum production. The overall mean of gum yield indicated by the model was 15.35 g/tree/season. Findings of the general linear model showed that the only significant main effects are tree diameter and time of tapping at medium stand density. Significant interaction between the tool (makmak) and the tapping date (first of October) at the same stand density was also detected by the model. Conducting experiments on the production of gum talha in permanent plot trials under different climatic regions of the Sudan is highly recommended.

Key words: *Acacia seyal*, gum talha, regression tree, stand density

INTRODUCTION
Forest management in Sudan mainly focuses on wood production, either for fuelwood or sawn timber, in plantations and/or natural forests (Elsiddig, 2003). However, non-timber forest products (NTFPs), such as gum Arabic[1] extracted from natural forests and/or plantations are also very

[1]According to the Joint FAO/WHO Expert Committee on Food Additives (JECFA, 1997) specification, gum Arabic is defined as the dried exudation obtained from the stems and branches of *Acacia senegal* (L.) Willdenow or closely related species of acacia gum (family Leguminosae) such as *Acacia seyal*

important and contribute significantly to rural and national economics of many African countries (Ballal, 2002; Chikamai, 1999; Seif el Din and Zarroug, 1998). Among these NTFPs is gum talha the natural product of *Acacia seyal*.

Gum talha is a natural exudate produces from the stem and branches of *Acacia seyal*. Gum talha has many traditional and industrial uses but generally friable and inferior to that of hashab, i.e., gum from *A. senegal* (Anderson *et al*., 1984; FAO, 1995; Hall and McAllan, 1993; McAllan, 1993). In Sudan, the gum from *A. senegal* and *A. seyal* are separated in both national statistics and trade (FAO, 1995). Unlike *A. senegal*, *A. seyal* in Sudan has not been cultivated for gum production (Fadl and Gebauer, 2004). Nevertheless, the species is reported to produce significant amount of gum (Ali, 2006; Fadl and Gebauer, 2004). The species grows naturally in the central clay plains of the Sudan (Mustafa, 1997) and extensively managed for firewood and charcoal production (Elsiddig, 2003). *A. seyal* is formed either pure stands of different densities or mixed stands associated with other tree species.

Little information is known about the potentiality of *A. seyal* to produce gum and the factors that affect the productivity of gum. Many authors, for example (Ahmed, 2006; Ballal *et al*., 2005); the International Institute of Environment and Development and the Institute of Environmental Studies (IIED and IES, 1990), investigated factors affecting the production of gum Arabic. Their studies focused on factors affecting gum hashab production. According to their investigations, physical (soils, topography, climate), biotic, socio-economic and institutional factors are the main factors influencing production of gum hashab. The information that is available about factors affecting the production of gum talha, such as time, tool and the position of tapping was illustrated in studies produced by other investigators (Ali, 2006; Fadl and Gebauer, 2004).

The present study focused on the influence of tree size, i.e., the Diameter at Breast Height (DBH) and stand density on gum talha yield. The effect of tapping techniques was also considered.

MATERIALS AND METHODS

The study site: Data for the present study were collected from Umfakarin reserve forest (Lat. 12° 29′-12° 35′ N and Long. 31° 17′ -31° 20′ E), South Kordofan, Sudan, between September 2007 and February 2008. The forest covers an area of about 2,689 hectares. In Sudan, an area where *A. seyal* occurs naturally, *Acacia seyal-Balanites aegyptiaca* zone, is classified as a low rainfall savannah on clay and extends from the Gedarif, Blue Nile and White Nile regions to the clay plains in Darfur and Kordofan regions (Badi *et al*., 1989; Harrison and Jackson, 1958; Sahni, 1968). Temperatures range from 30-35°C. Annual rainfall ranges from 400 to 1000 mm and the species flourishes along seasonal water courses in areas where annual rainfall is less than 400 mm (Vogt, 1995). Seasonal flooding is the most conspicuous feature in the Umfakarin forest. Sandy, cracking clay and non-cracking sandy clay (locally: gardud) are the prevailing soils in the study area. In the northern parts of South Kordofan some scattered thorny trees (acacias) dominate the vegetation cover. The density of vegetation cover increases from north to south where formations of poor *A. senegal* and *A. mellifera* pave the way for *Acacia seyal-Banalities* woodland and other plant formations.

Data collection: In this investigation, three stand densities of *A. seyal* namely dense, medium and slight were distinguished based on the number of trees per hectare. A total of 482 target[2] trees of *A. seyal* were selected based on diameter at 0.25 m height ($d_{0.25}$) for quick determination because

[2]The term target tree, in this study, refers to the tree that selected for gum production experiment

A. seyal is a multi-stemmed tree. In each stand density, the following diameter categories for the target trees were covered: $d_{0.25}$ = 9-11.5, 13.5-16, 18-20.5 and above 21 cm. The diameter at breast height DBH was measured for all target trees in each sand density.

Selected trees were exposed to tapping, on the first of October, fifteenth of October and first of November, using local tools (sonki and makmak) in addition to untapped trees used as a control. Both tools were used by Ali (2006) and Fadl and Gebauer (2004) for tapping the same species in Umfakarin forest. The first collection (pick) of gum was commenced fifteen days after tapping while the subsequent (7-9 pickings) were done at an interval of fifteen days. Gum samples collected from each target tree were dried at room temperature for 72 h and then weighed on a sensitive balance to the nearest 0.001 of a gram.

Data analysis: The total gum yielded by each target tree per season was determined by summing up the gum samples collected from all pickings. Gum production per unit area was also determined. Gum talha yields were classified into six yield classes (g) namely, ≤50, 51-100, 101-150, 151-200, 201-250 and ≥251 g. In each yield class, number of trees and total gum yield (g) were determined. Additionally, average gum talha yield (g) per tree in different stand densities were obtained.

Regression tree package in R program and regression analysis under GLM (general linear model) univariate procedure in SPSS for windows (version 17.0) were used for data analysis. Regression tree was used for the exploration of factors affecting gum talha yield and to predict the mean value of gum yield obtained from *A. seyal* trees as a result of different tapping treatments. The data were split into three groups, i.e., by stand density and the analysis was performed. To explore the differences in gum yield among the significant variables, a post hoc test after Analysis of Variance (ANOVA) based on Scheffe test was carried out. To assess factors affecting yield of gum talha, the regression model was used. The model based on a set of independent variables. This set includes stand density, tapping tool and the date of tapping in addition to DBH. It was also assumed that these explanatory variables have a positive effect on gum yield. The mathematical formula of this model can be expressed as follows:

$$y = f(d, T, t, DBH)$$

Where:

y	=	Yield (g)/tree/season
f	=	Function
d	=	Stand density
T	=	Tapping tool
t	=	Date of tapping
DBH	=	Diameter at breast height (cm)

RESULTS

Total gum and number of trees per yield class in addition to average gum yield per tree in different stand densities were obtained and summarized in Table 1. Average gum yield was estimated as 12, 13.24 and 20.58 g per tree per season in dense, medium and slight stand density, respectively. Gum talha production is ranged between 3.59 to 4.78 kg ha^{-1}. In all stand densities, high number of trees (between 41-53%) in the lowest gum yield class (≤50 g) is detected. The maximum total gum yield was obtained in the lowest yield class (≤50 g) by 84 observations in dense stand density. Number of trees in the second yield class upwards is exhibiting less than 4% of the selected trees in dense stand density. In medium and slight densities, the number of trees in

Table 1: No. of trees, total and average gum talha yield (g) per yield class and production (kg/ha) in different stand densities

Stand density	N_0	Gum yield class (g) ≤ 50	51-100	101-150	151-200	201-250	≥251	Average yield (g)	Production (kg ha^{-1})
Dense	68	1076.07(84)	199.64(3)	101.46(1)	0.00(0)	234.38(1)	293.42(1)	12.06	4.78
Medium	85	809.91(65)	292.16(4)	560.39(4)	0.00(0)	202.2(1)	254.28(1)	13.24	3.59
Slight	74	830.57(69)	838.18(12)	368.62(3)	515.93(3)	204.53(1)	616.8(2)	20.58	4.30

N_0 = No. of non-yielding trees; No. of observations (dense = 158; medium = 160; slight = 164); No. of trees/ha (dense = 396, medium = 271, slight = 209). Values in parenthesis is number of trees per yield class

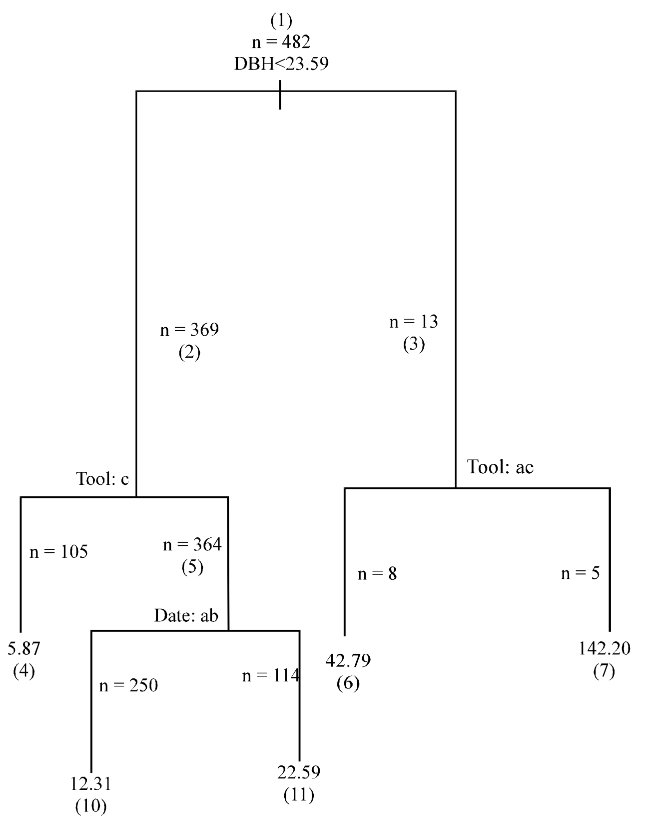

Fig. 1: Regression tree model for predicting yield of gum talha. In parentheses are node number; n is number of observation per node; means of gum yield are shown in the terminal nodes (4, 6, 7, 10 and 11)

the same yield classes represents about 6 and 13%, respectively. The high yielding trees, i.e., classes 151-200 upwards constitute about only 2% of the total target trees (482). The non-yielding trees constitute about 43, 53 and 45% of the selected trees in dense, medium and slight densities, respectively (Table 1).

Average gum yield and number of individual trees per each tapping treatment were obtained and presented in Table 2. Trees tapped by sonki (n = 16) on first of October at medium stand density have the highest gum yield with a value of about 56 g/tree/season. The minimum gum yield (2 g/tree/season) obtained on fifteen of October by 18 untapped trees in slight stand density.

Figure 1 shows that the model contains of 5 terminal nodes (or leaves, i.e., 4, 6, 7, 10 and 11). DBH, tapping tool and date of tapping are contributed in the tree building. The most important

Table 2: Descriptive statistics (based on 482 trees) for gum yield (g) for the different tapping treatments for *Acacia seyal* in Umfakarin forest, South Kordofan, Sudan

Stratum	Tool	Date	N	Min.	Max.	Mean	SD
Dense	Makmak	Fifteenth Oct.	22	0.000	234.377	17.364	49.952
		First Nov.	18	0.000	43.734	10.938	13.434
		First Oct.	17	0.000	293.423	30.143	70.639
	Sonki	Fifteenth Oct.	18	0.000	16.254	3.784	5.1568
		First Nov.	19	0.000	101.459	13.602	23.837
		First Oct.	15	0.000	34.366	11.738	12.451
		Fifteenth Oct.	15	0.000	24.891	4.362	7.487
	Untapped	First Nov.	14	0.000	57.168	7.701	15.935
		First Oct.	20	0.000	74.094	6.889	16.862
Medium	Makmak	Fifteenth Oct.	23	0.000	87.334	8.585	19.295
		First Nov.	21	0.000	148.215	12.631	33.169
		First Oct.	32	0.000	140.059	9.580	26.717
	Sonki	Fifteenth Oct.	23	0.000	137.640	11.021	29.062
		First Nov.	23	0.000	24.238	4.487	7.679
		First Oct.	16	0.000	254.275	56.067	76.965
	Untapped	Fifteenth Oct.	7	0.000	40.620	6.202	15.213
		First Nov.	15	0.000	25.757	3.506	8.656
Slight	Makmak	Fifteenth Oct.	24	0.000	93.806	16.603	28.590
		First Nov.	27	0.000	342.572	25.779	66.848
		First Oct.	21	0.000	187.489	32.712	50.748
	Sonki	Fifteenth Oct.	19	0.000	171.333	17.094	43.234
		First Nov.	21	0.000	204.529	22.545	49.988
		First Oct.	16	0.000	274.288	36.629	71.266
	Untapped	Fifteenth Oct.	18	0.000	13.195	2.008	3.964
		First Nov.	9	0.000	131.521	14.613	43.840
		First Oct.	9	0.000	18.001	4.585	7.391

N = No. of trees per treatment; SD = Standard deviation

explanatory variable influencing gum yield, is the DBH. The model partitioned the data set into two, below and above the DBH threshold value (23.95 cm) followed by splits for the subsequent data subset. Only 3% of the data set was split when DBH is greater than threshold (see the right-hand branch of the Fig. 1). The model starts with the root node (1) which contains all of the data set (n = 482). The overall mean of gum yield estimated by the regression tree model was 15.35 g. The predicted mean values of gum yield (in terminal nodes) and number of cases (n) for each node are provided in the same figure. In the left-hand branch and in terminal node (4), the minimum gum yield value (5.87 g) is given by 105 untapped trees when DBH is less than the threshold. In node 7 in the right-hand branch, the maximum gum yield (124.70 g) is given only by 5 trees when DBH larger than the threshold. The model was also used to calculate the mean value of gum yield based on the DBH threshold. In Fig. 2, the vertical dotted line denotes the threshold value of DBH. The two horizontal lines show the mean values of gum yield 13.53 and 81.10 g below and above the threshold, respectively. As can be seen from this Fig. the right-hand side of the vertical dotted line contains only 13 individuals which render further subdivision ineffective. However, further subdivision for the data below the threshold is possible.

The results of regression analysis under univariate General Linear Model (GLM) showed that at least one treatment is different (p = 0.011). The only significant main effects are DBH and time

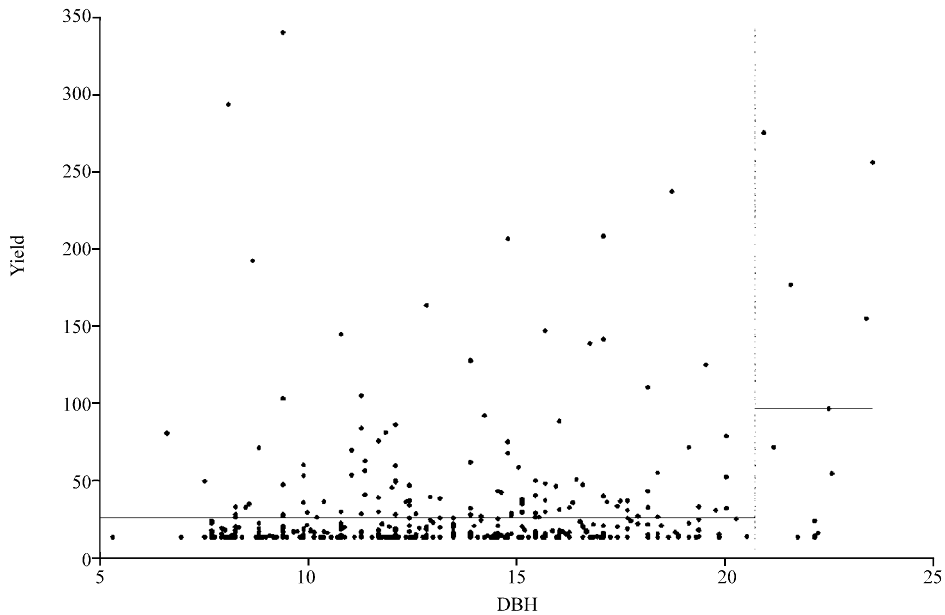

Fig. 2: Regression tree model for predicting mean gum talha yield. Vertical dotted line indicates DBH threshold (23.95 cm); the two horizontal lines show the mean values of gum yield 13.53 and 81.10 g below and above the threshold, respectively

Table 3: Scheffe test (Post-hoc-test) after ANOVA for gum talha yield derived from natural *A. seyal* for different tapping dates in Umfakarin forest, South Kordofan, Sudan

Stratum	Date (X)	Date (Y)	Gum mean difference (X-Y)	SE	Sig.	95% CL Lower	95% CL Upper
Dense	1	2	10.359	5.502	0.174	-3.256	23.974
		3	4.848	5.474	0.676	-8.698	18.395
	2	3	-5.511	5.528	0.610	-19.191	8.169
Medium	1	2	16.967	7.023	0.057	-0.394	34.327
		3	19.158*	6.839	0.022	2.253	36.063
	2	3	2.191	6.905	0.951	-14.878	19.261
Slight	1	2	15.761	9.467	0.253	-7.655	39.176
		3	5.747	9.540	0.834	-17.848	29.341
	2	3	-10.014	8.939	0.535	32.123	12.095

*The mean difference is significant at the 0.05 level. Date: 1 = 1st of October, 2 = 15th of October and 3 = 1st of November; X and Y are gum means; SE is standard error of the mean; CL is confidence limit

of tapping at medium stand density. Further inspection of ANOVA results showed significant interaction between the tool (makmak) and the tapping date (first of October) at a medium density. Results of post-hoc test indicate significant difference ($p<0.022$) in gum yield between first of October and first of November only in medium stand density. Table 3 provides information on whether the gum yield averages are significantly ($\alpha = 0.05$) different from each other. More details about the differences in gum yield are presented in the table of Homogenous subset (Table 4). It can be seen from the data in this table, the output of Scheffé test produces average gum values either in one subset or two subsets for each tapping date. Averages within the same subset are not

Table 4: Homogenous subset for average gum talha yield (g/tree/season) based on Scheffé test

Slight			Medium				Dense		
		Subset			Subset				Subset
Date	N	1	Date	N	1	2	Date	N	1
2	59	12.811	3	59	7.136		2	50	5.531
3	57	22.825	2	53	9.328	9.328	3	51	11.042
1	46	28.571	1	55		26.294	1	52	15.890

Means for groups in homogeneous subsets are displayed; Date of tapping: 1 = 1st of October,2 = 15th of October and 3 = 1st of November

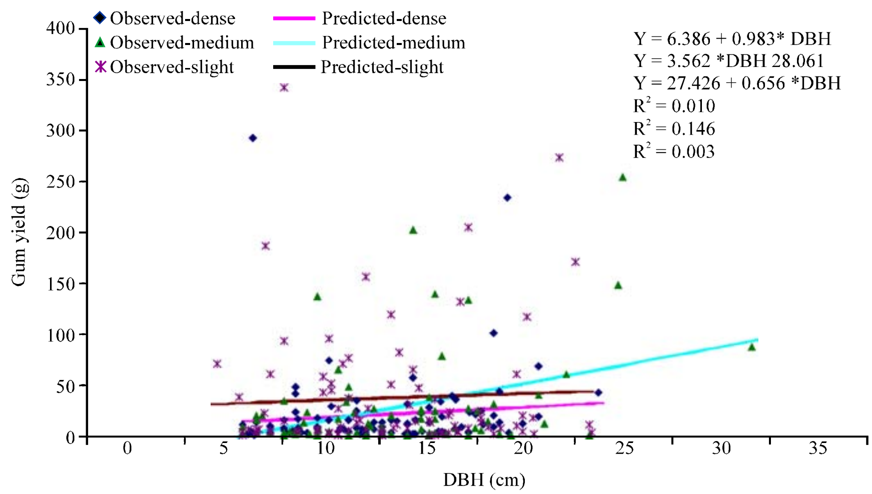

Fig. 3: Gum talha yield in relation to tree diameter in different stand densities. No. of observations per stratum (dense = 90, medium = 75 and slight = 90)

significantly different (α = 0.05) from each other. For example, in the case of one subset in dense and slight densities, there is no significant difference in gum yield between the different tapping dates. However, in the case of medium stand density, there are two subsets. This means, in the first subset, there is no different ($p = 0.943$) in gum yield between fifteen of October and first of November. In the second subset, there is also no different between first and fifteen of October. However, gum yield is different ($p = 0.050$) between first of October and first of November.

Taking into account only the trees with yield and regardless of the gum tapping treatments, the relationship between gum yield and DBH for the different three stand densities was tested. Observed values and the modelled one (smooth lines) are presented graphically in Fig. 3. The maximum R^2 value (0.146) was obtained in medium stand density. The data dots are randomly distributed and indicating high variability of yield in all stand densities. The general trend is that gum yield increases when DBH increases. The dense density, however, produces curve spaced below the curves of medium and slight densities.

DISCUSSION

Gum talha has a significant contribution to the total Sudanese gum Arabic production. However, yield per tree (15 g) in this investigation is very low in comparing to gum hashab from *A. senegal* (250 g) estimated by other authors (FAO, 1978; IIED and IES, 1990). This finding is similar to that estimated by Hineit (2007) who revealed that *A. seyal* trees, of DBH 4-7 cm, in Eastern Sudan produces an average gum yield accounts to 14.8 g per season. Gum production per hectare in the present study did not exceed 4.8 kg which is close to the estimates (2.5 kg ha^{-1}) reported by Mohammed and Röhle (2009). The low production of gum could be associated to the capability of tree to produce gum or other factors such as site conditions. The percent of non-yielding trees also contribute to the low production of gum talha. In the present study, the non-yielding trees constitute almost more than 46% of total number of trees (482) selected for gum production. On the other hand, trees that produce less than 50 g of gum represent between 41-53% of the selected trees.

Factors affecting yield of gum talha: To manage *A. seyal* natural stands for the production of gum talha, factors affecting the production of gum should be identified and assessed. In the present investigation, a regression tree was used to explore the most important factors determining gum productivity. The influence of stand density, the tool and date of tapping, in addition to the Diameter at Breast Height (DBH) on gum yield were tested by a regression tree package. Based on the results of the regression tree, stand density was the only variable that did not contribute to the tree model, signifying that stand density had no significant influence on gum yield. This result is consistent with the findings of Mohammed and Röhle (2009) who found that stand density has no significant effect on gum talha yield. On the other hand, tool type and the date of tapping contributed in tree model, indicating that both have an influence on gum yield. The present findings seem to be consistent with those of Fadl and Gebauer (2004) study that investigated the effect of tapping tools on the productivity of gum talha and revealed that tapping has positive impact on gum yield. In contrast to the results of this study, other research (Ali, 2006; Mohammed and Röhle, 2009) revealed that the tool type and date of tapping have no significant effect on gum talha productivity.

Gum yield in relation to tree diameter: Based on the results of regression analysis (r = 0.003-0.146), gum talha yield was found to be positively yet weakly associated with DBH in different stand densities. A similar weak positive correlation (r = 0.138) between gum talha yields and DBH was reported by Ali (2006). In contrast to these findings (Hineit, 2007) revealed no relationship between gum talha yield and DBH. The weak correlation between gum talha yields and tree diameter could be attributed to genetic and environmental factors. Further studies on the gum yield of *A. seyal* under different site conditions could be of importance in order to prove this assumption. The effect of environmental factors on gum hashab production was investigated by Ballal (2002) and Ballal *et al.* (2005) and revealed that the yield of gum is highly affected by rainfall and correlated positively with annual rainfall amounts.

In comparing the results of the regression tree analysis with GLM, the results of the later indicate that the only significant factors influencing gum yield are DBH and the time of tapping, at medium stand density. Generally, the results of the two methods of analysis seem to be similar.

CONCLUSION

This research paper provides results on the possibility of managing *A. seyal* var. *seyal* for production of gum talha. The ability of *A. seyal* to produce gum talha was assessed by exposing the trees to different tapping techniques. The findings of the study revealed that production per unit area is low (not exceeding 4.78 kg ha^{-1}). The most important variables influencing gum production were found to be the Diameter at Breast Height (DBH) and time of tapping. The decision to tap or not to tap is based on the production of gum per unit area. Based on these findings, tapping *A. seyal* is economically infeasible. Conducting experiments on the production of gum talha in permanent plot trials under different climatic regions of the Sudan is highly recommended.

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