Effect of Tree Height and Girth on Gum Yield of *Acacia senegal* L. in Savanna Woodland of Nigeria

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Abstract

Parameters influencing gum yield such as tapping techniques and soil mineral elements had earlier been investigated while there is dearth of information on effect of morphological characteristics on gum yield. This study investigated effects of height and girth on yield of *Acacia senegal* L. in the natural forests. Three heights and girth classes were purposely selected. Trees which heights and girth fell within those classes were selected randomly and tapped at constant height classes with varying girth classes. Exudates were collected, weighed and recorded according to height and girth class respectively. Descriptive and ANOVA results showed that when total tree height was lower than 2.0 m, gum yield increased as tree girth goes higher from 35 - 54cm (163.6 - 209.7g). Tree girth significantly affected gum yield ($p \leq 0.05$) and trees which total heights were lower than 2.0m (maximum of 1.95m) and girth higher than 54cm (maximum of 65cm) produced the highest mean gum yield. Silvicultural practices that could bring about increase in girth such as early pruning and re-spacing which is applicable to plantation trees could also be carried out on the natural forest trees to increase gum yield.

Key words: *Savanna woodland, Acacia senegal, Gum yield.*

1. Introduction

Acacia senegal L. (Willdenow) is a multipurpose sub-saharan tree species from which gum Arabic is collected. The term gum Arabic is used with varying definitions by different groups of people. It acquired its name because the early traders were Arabs (Maydell, 1990). In the context of its use as a food additive, the most current international specification published by FAO (1990), defines Gum Arabic as the "dried exudation obtained from the stems and branches of Acacia senegal L. (Willdenow) or closely related species.

FAO (2004) identified gum Arabic as a potential commodity in world trade while it has been the main stay of the Sudanese economy for over 400 years (Lawal, 1998). Thompkins (2007) reported that in the days of the Egyptian Pharaohs, gum Arabic was essential for mummification, and since Biblical times, it has been used to maintain the integrity of paints. Milbak (2007) described it as a natural emulsifier. This means that it can keep together substances which normally would not mix well. Pharmaceutical companies use it to keep medicine from separating into their different ingredients, and a dab of gum Arabic makes newspaper ink more cohesive and permanent.

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In recent time, gum Arabic has been brought into prominence in international diplomacy. It is being used as a tool by Sudan against sanctions by the United States. According to report in a press conference held at the Washington Press Club on 30th May 2007, John Ukec Lueth, Sudan's ambassador to the United States threatened to stop exportation of gum Arabic from his country if sanctions were imposed. America's Coca-Cola derives 80% of its emulsifier from gum imported from the Sudan. Gum Arabic keeps sugar suspended so that it would not precipitate to the bottom of the drink. Many uses of gum Arabic in folk medicines have been reported by Wyk and Erik (2005), FAO (1992), Naude (1994) and NAS (1981).

Gum export

The export of gum Arabic to Europe started in Nigeria in 1914 (FDA, 2001) before oil exploration, but unfortunately it has been abandoned for oil export. The world demand for gum Arabic has increased tremendously over the years. However, its market price has been declining since 1991 when it was sold at $6,000 per ton for the highest grade I gum and by 1994, the same grade was sold for $4,000 (FDA, 2002). The Nigerian gums are principally exported to Europe, Japan, USA, Hong Kong and India. In 1995, total export to the European Union (EU) was 3,683 metric tons valued at $5,960,000, while India imported a total of 2,542 metric at $1,150,026 (Lawal, 1998). Thus, the EU is the major importer of Nigerian gums, followed by India and then the USA.

Exports of gum Arabic from Nigeria have declined due to declining prices in international markets. Gums for export are generally graded into two; grade 1 and grade 2. Grade 1 gum are those collected purely from *Acacia senegal*, while grade 2 gum are those collected from *Acacia seyal* and other Acacia species. Grade 1 gum is the higher quality and more preferred but farmers and buying agents do adulterate the grade 1 gum with other gum which is not from *Acacia senegal*.

In reality with the present economy, the Federal Government of Nigeria on the 4th of September, 2009 announced a re-direction of attention to the production of gum Arabic, describing it as a lost cash crop. It therefore calls for groups and private participation in the production of which plantation establishment is the only option if the over-all national production must be raised. However, most of Nigeria's gum comes from the wild (FDA, 2002) and Unanaonwi (2008) reported that gum yield on a per tree basis was higher in the natural forest than in the plantation. The question then arises as to what silvicultural interventions could be employed to improve yield in the natural forest which is the current main source of Nigeria's gum. The aim of this study is to investigate the effect of tree height and girth on gum yield in the natural forest.

2. Materials and Methods

2.1 Study site/Area

This study was conducted at Gummi forest in Zamfara State, Nigeria. The area lies approximately between latitudes 11^0 30` and 25$^0$ 15` North, and longitudes 40^0 50` and 70$^0$ 15` East. The area experiences a long dry season from October to May and a short rainy season from June to September. These two seasons are attended with two major wind currents namely the cold easterly and the southwesterly wind. The dry season consists of a cold dry spell, usually referred to as hamatam, roughly from November to January, followed by a hot dry spell from February to April (Singh and Babaji 1989). Rainfall in the area is erratic in nature, small in quantity with an annual mean of 724mm and of uneven distribution with a peak in August. The minimum and maximum temperatures fluctuate between 15^{0}C and 41^{0}C, January and April respectively (ZADP, 1996). The state is located within the northern guinea savanna. The vegetation is characterized by tall grasses and shrubs; and short scattered trees of woodland. Common tree species that could be found are *Acacia senegal*, *A. notilica*, *A. albida* and *Khaya* spp. among others. These species though natural, have gone through bush fires and exploitation over the years.

Multistage sampling method was used. This involved dividing the whole stands into blocks, and then sub-dividing each block into plots. One plot in each block was then studied, after adopting the random-within-block sampling technique.

The 900 ha forest was demarcated into 20 blocks each of 45ha. Each block was then divided into plots 100x100m. These were finally sub divided into 50x50m sub-plots. Nine sub-plots were randomly selected from a randomly selected plot within each block, for data collection. Ten trees per sub-plot were purposely identified and measured according to height and girth class combination, with each sub-plot being assigned with a particular height and girth combination. Tree heights were classed into three as follows: <2.0m; 2-2.5m; and >2.5m. The range of class was based on the general height of trees as pictured from the data. Tree girth was equally classed into three of 35-44cm; 45-54cm; and >54cm. This range was based on the overall tree girth as represented in the primary measurements.

The assigned tree and girth combinations were:

1. Trees with height < 2.0m within girth class of 35-44cm.
2. Trees with height < 2.0m within girth class of 45-54cm.
3. Trees with height < 2.0m with girth class >54cm.
4. Trees with height 2 –2.5m within girth class of 35-44cm.
5. Trees with height 2 –2.5m within girth class of 45-54cm.
6. Trees with height 2 –2.5m with girth >54cm
7. Trees with height >2.5m within girth class of 35-44cm.
8. Trees with height >2.5m within girth class of 45-54cm.
9. Trees with height >2.5m with girth class >54cm.

2.2 Data collection

Height, girth and yield

Measurements were carried out for three tapping seasons (three years). Tree height was measured with graduated wooden pole and girth was measured with calibrated tape at 1.3m above ground (1UFRO standard) and recorded according to their respective height/class combinations. Trees were tapped using short cutlasses by slashing 20cm deep in a slanting position on one side of the stem as described by Unanaonwi (2009). Exudates were allowed to dry and were collected after four weeks and weighed accordingly. There were four further collections, weighing and recording fortnightly with the use of simple weighing scale.

2.3 Data Analysis

Data were analyzed using the SPSS. Descriptive statistics was used while analysis of variance was conducted to test the hypotheses.

3. Results and Discussion

Influence of tree physical characteristics such as heights and girths have been widely used in yield estimates in forestry where timber yield in volumes or logs of round wood draws heavily from information gotten from height and diameter at breast height (dbh). These parameters could also be used to estimate gum yield or yield of exudates of any tree species approximately.

When the height was held at a constant of <2.0m with a maximum height of 1.95m, the yield increased along with increasing girth class, with maximum yield occurring at girth class >54cm (Table 1). It means that if the girth continues to increase at a constant tree height of <2.0m, yield would be increasing. Height in that case does not influence yield but tree girth does. Increasing tree girth would

therefore bring about increase gum production provided tree height is kept at about 1.95m below 2.0m. Shorter trees tend to produce larger girth especially in the natural forest where trees do not undergo competition for light and space. The process of competition for light keeps tree growing taller with thinner bole and circumference. Larger tree girth appears to favour the extension of the laticiferous layers where latex is stored. This layer would be small and thin in trees that are tall resulting into lower gum yield.

Table 1.Result of mean gum yield with respect to height and girth combinations in natural forest

	Height (m)			Girth (cm)			Yield (g)		
	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
H < 2.0m; Girth 35-44cm	1.5	1.0	1.25	44	35	41.3	204	101	163.6
H < 2.0m; Girth 45-54cm	1.4	1.1	1.25	54	46	47.5	215	80	174.1
H< 2.0m; Girth > 54cm 2.0	1.0	1.50	65	58	60.1	242	180	209.7	
H 2 –2.5m; G 35-44cm 2.0	2.0	2.00	41	39	40.3	212	110	162.9	
H 2 –2.5m; G 45-54cm 2.1	2.0	2.05	53	47	50.6	230	108	157.7	
H 2 –2.5m; G >54cm	-	-	-	-	-	-	-	-	-
H >2.5m; G35-44cm	-	-	-	-	-	-	-	-	-

Height held constant at lower than 2.0m, yield increases. Height held constant at 2-2.5m, yield decreases with increasing girth. zero effect on yield as girth rises to greater than 54cm.

When the height was increased to a constant of 2-2.5m within the first girth class, yield dropped by approximately 23%. On further increase of girth to the second class, yield dropped by 75%. On increasing girth further to >54cm, no tree was encountered within that girth class. Since yield dropped within the first girth class on increasing the height, the 23% dropped in yield is attributed to the increased height from <2.0m to 2-2.5m. On the other hand, girth still had greater influence on yield as the first increase in girth class (45-54cm) leads to 75% increase in yield. The yield trend is on the reverse because of the impact of tree height but boosted by increasing girth. This further strengthened earlier hypothesis that yield would be on the increase at varying girth classes as long as tree height is brought to below 2.0m.

The maximum height for that class was 2.08 while the maximum girth for the class was 53cm. It means that girth class beyond 54cm within height of 2-2.5m will yield no result in terms of gum yield. There were no trees found within height >2.5m and the highest tree was 2.08m. Silvicultural manipulations for increased tree height would therefore not favour increased gum yield.

Tree girth significantly affected gum yield ($p \leq 0.05$) which confirmed the observation in Table 1. Silvicultural interventions that could result to increased tree girth such as crown pruning at younger age of tree would be appropriate for increased gum yield. Plantation trees tend to grow taller than those in the natural forest due to competition factors which depend on planting distance. However, for large scale production of gum Arabic, plantation establishment will be a good option if the planting distance is wide enough and epical pruning is carried out at the appropriate time to delay tree height while at the same time increase tree diameter. Three girth classes were used in the study and it was therefore necessary to identify which of the girth class gave the highest yield figure. Table 2 shows that trees with girth >54cm with <2.0m in height produced the highest amount of gum. No tree was encountered beyond the maximum height of 2.08m thus imposing a limit to the investigation. That is to say, the highest tree in the natural forest was 2.08m.

Table 2. Results of Duncan multiple range test for girth class and yield

Height and Girth class (m; cm)	Yield (g)
<2.0m; 35 – 44cm	163.225 a
<2.0m; 45 – 54cm	176.800 a
<2.0m; >54cm	209.700 b

Means with the same letter are not significantly different at α = 0.05

4. Conclusion

The study has shown that tree parameters such as girth and height have effects on the amount of gum yield of *Acacia senegal* with larger tree girth giving higher amount of gum yield. The effects of height on yield were not significant ($p \leq 0.05$). Apart from factors such as site quality, soil nutrient considerations, and tapping techniques, tree parameters such as height and girth also affect yield of exudating tree species, and should be considered when evaluating yield factors. Keeping tree height to below 2.0m and allowing girth increment of about 60cm would bring the best yield result. Farmers have better chance of increasing the amount of gum harvested if trees are manipulated such that it brings about increase in girth. Prescribe burning and apical pruning during growth period would be an option in this respect, since it reduces profuse apical growth which brings about increase in tree height, for increase tree diameter.

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