Sudan University of Science and Technology

College of Graduate Studies

Effect of some tapping tools and intensity on gum Arabic yield of *Acacia Senegal* and *Acacia seyal* trees in clay soil of Gedarif State, Sudan

تأثير بعض أدوات الطق و كثافته على إنتاج الصمغ العربي لأشجارالهشاب والطلح فى التربة الطينية- ولاية القضارف-السودان

A Thesis submitted For Partial Fulfillment of the Requirements for the M.Sc.Degree in Forestry Science

By

Musa Ahmed Musa Ahmed

B.Sc. (Forestry science)-2003

Supervisor
Dr. Abdel Wadood Abdullah

Department of Wood and Non Wood products
Faculty of Forests and Ranges Science
Sudan University

January -2021

Dedication

To my parents

To my wife, children, sisters, brothers,

All my family, colleagues and friend

To all people in the Sudan

Acknowledgements

I wish to praise and thank Allah, who helped me to carry out this research and facilitated many things for me to complete this work. I wish also to express my sincere appreciation to my supervisor Dr. Abdel wadoud Abdullah Al-Khalifa for his continuous guidance and encouragement throughout this study. I would like also to extend my thanks to the Staff of the College of Forestry and Range Science, Sudan University of Science and Technology for their help during data analysis. Special thanks also go to my colleagues at Elrawashda and Saraf Saeed forests who greatly helped me during the experimentation part of this research.

Effect of some tapping tools and intensity on gum Arabic yield of *Acacia Senegal* and *Acacia seyal* trees in clay soil of Gedarif State, Sudan

Abstract

This research aimed to study the effect of some tapping techniques on gum Arabic yield of *A. Senegal* and *A. seyal* in clay soil of Gedarif State in eastern Sudan. Tow Experiment were conducted. The objective of the first experiment was to investigate the effect of tapping tool and tapping intensity on gum yield of *A. Senegal*. This experiment was conducted for two consecutive seasons 2014/2015 and 2015/ 2016 at Elrawashda Reserve Forest (latitude 14˚6' - 14˚24'N and longitude 35˚32' - 35˚49'E) in Gedarif State on 15 years old *A. senegal* plantations.. Randomized complete block design with four replicates arranged in a factorial setting (3×2) was used. The first factor was tapping intensity with three levels, being tapping seven, five and three branches and the second factor comprised two types of tapping tool, namely, axe and sonki. Tree tapping for both seasons commenced in 15th of November and the first picking was conducted after 45 days, and then three subsequent picks were made with two weeks interval. Collected gum was air dried and weighed in grams for each picking. Analysis of variance was conducted using SAS statistical software version 9. (SAS Institute Inc., 2003). Duncan Multiple Range Test was used to separate between means.Results showed the effect of both tapping intensity and taping tool to be significant on mean gum yield per tree during both seasons ($p=0.001$). Gum produced under seven branches tapping intensity was 62.1 and 59.5 g/tree for both seasons (2014/2015 and 2015/ 2016 successively)which was not significantly different from that produced under five branches level 56.4 and 52.1 g/tree. However, the three branches intensity level produced significantly less gum (33.3 and29.4 g/tree). The effect of tapping tool was observed to be significant during both seasons ($p<0.05$).Trees tapped with the sonki gave higher yield (58.6 and 55.7 g/ tree) during seasons 2014/15 and 2015/16 successively, than those tapped with the axe which gave 42.5 and 38.2g/ tree.During the first season 2014/2015 the effect of tapping intensity on gum yieldg/picking) was significant ($p> 0.05$) for all pickings. The second picking at seven branches level produced 21.7 g, whereas the fourth picking at level three branches gave 6.5 g. The effect of tapping tool on gum yield (g/picking) was significant ($p< 0.001$). In all pickings, except in the second, sonki produced significantly higher gum yield than the axe. During the second season 2015/16 variations in mean yield (g/picking)followed the same pattern as in the previous season. Except in the second picking the tool type effect was observed to be significant on gum yield (g/picking).

Trend in gum yield (g/picking) in relation to season showed that maximum yield was obtained in the second picking, followed by a steady drop in the third and the fourth picking.The second experiment was carried out at Saraf Saeed forest in Gedarif State to study the effect of induced injury and tree size on gum yield of *A. seyal*. A factorial (2×4) experiment was carried out. The first factor comprised two levels of tree size: medium (15-20 cm in diameter) and large (20-25 cm in diameter). The second factor constituted four levels of induced injury being: 1, 3 and five injuries, besides the control. Injuries were made on the main stem. A randomized complete block design (RCBD) was used with three replications. Tapping was carried out on the 1st of November, then first and subsequent picks were done in interval of one month. After having been dried at room temperature for 48 hours, the collected gum was then weighed and recorded. Analysis of variance was conducted using SAS statistical software version 9. Duncan Multiple Range Test was used to separate between means. The effect of both tree size and number of induced injuries was found to be insignificant (P = 0.252 and 0.458 respectively). *A. seyal* trees subjected to five injuries produced the higher gum yield (30.8 gram) which is not significantly different from yield of trees subjected to one and three injuries which gave gum yields of 28.8 and 27.8 grams respectively. Gum yield of the control trees (31.2 g) was higher than the yield of trees injured one and three times, but there is no significant difference between them. The effect of tree size was found to be insignificant. Large trees gave mean gum yield of 26.2 grams whereas medium trees gave 30.5 grams. The study recommended tapping five branches of *A. Senegal* trees using sounky as a tapping tool in Gedarif State.

تاثيربعض أدوات الطق و كثافتة على إنتاج الصمغ العربي لأشجارالهشاب والطلح فى التربةالطينية- ولاية القضارف-السودان

الملخص

هدف هذا البحث لدراسة تأثير بعض تقانات الطق على انتاج الصمغ العربي لأشجار الهشاب و الطلح في التربة الطينية في ولاية القضارف في شرق السودان. تم اجراء تجربتين، هدف التجربة الاولى هو بحث تأثير الة وكثافة الطق على انتاج الصمغ العربي من شجرة الهشاب. اجريت التجربة لموسميين متتاليين ٢٠١٤\٢٠١٥ و ٢٠١٥\٢٠١٦ في غابة الرواشدة المحجوزة(خط عرض ١٣,٦ – ٨٤,٢٤ شمال وخط طول ٣٥,٣٢ -٣٥,٤٩ شرق) في ولاية القضارف على اشجار هشاب مزروعة بعمر ١٥ سنة وتم استخدام التصميم المربعات كامل العشوائيةباربعة مكررات بنسق تجربة عامليه (٢*٣)العامل الاول كان كثافة الطق بثلاثة مستويات هي:طق ٧، ٥ و ٣ افرع و العامل الثاني هو اله الطق بمستويين هما الفأس و السونكي. بداية الطق في كلا الموسمين كانت في ١٥ نوفمبر و اخذت اللقطة الاولى بعد ٤٥ يوم، اخذت بعدها ٣ لقطات متتالية كل ١٥ يوم. تم تجفيف ووزن الصمغ لكل نقطة. استخدم برنامج SAS لاجراء التحليل الاحصائي وتم استخدام اختبار دنكن للمدي المتعدد للفصل بين المتوسطات، اوضحت النتائج وجود اثر معنوي لآلة الطق على انتاج الصمغ في شجرة الهشاب في خلال الموسمين باحتمالية اقل من ٠.٠٥ . الصمغ المنتج عند الطق بمستوى ٧ فروع كان ٦٢.١ و ٥٩.٧ جم/شجرة للموسمين ٢٠١٤\٢٠١٥ و ٢٠١٥\٢٠١٦ على التوالي والذي لا يختلف معنويا عن الطق على مستوى ٥ افرع والذي اعطى ٥٦.٤ و ٥٢.٦ جم/شجرة، بينما الطق على مستوى ثلاثة افرع (٣٣.٣ جم/شجرة) كان معنويا اقل.تأثير الالة على الانتاج كان معنويا في كلا الموسمين (احتمالية اقل من ٠.٠٥)، الاشجار التي طقت بواسطة السونكي اعطت انتاجا اعلى (٥٨.٦ و ٥٥.٧ جم/شجرة) في خلال الموسمين ٢٠١٤\٢٠١٥ و ٢٠١٥\٢٠١٦ على التوالي اكثر من تلك الذي استخدم فيها الفأس والتي اعطت ٤٢.٥ و ٣٨.٢ جم\شجرة.في خلال الموسم الاول كن تاثير كثافة الطق علي انتاج الصمغ بالجرم/طقة تاثيرا معنويا (احتمالية≤ ٠.٠٥) في كل اللقطات.اللقطة الثانية عند مستوى ٧ افرع اعطت ٢١.٧ جم بينما اعطت اللقطة الرابعة ٦.٥ جم. في كل اللقطات معدا الثانية السونكي اعطى انتاجا معنويا اكثر من الفاس. في الموسم الثاني الاختلافات في انتاج الصمغ اتبعت ذات نمط الانتاج كما كان في الموسم الاول. كلا الة الطق و كثافة الطق كان لهما اثر معنوي على الانتاج(احتمالية <٠.٠٥). في كل اللقطات لم يختلف الانتاج معنويا عند مستوى ٧ افرع عن انتاج ٥ افرع. معدا في اللقطة الثانية كان هناك تأثير معنوي لالة الطق على انتاج الصمغ. نمط انتاج الصمغ حسب الموسم اوضح أن اعلى انتاج حصل عليه كان في اللقطة الثانية ثم كان هناك انخفاض تدريجي منتظم في الانتاج في اللقطات الثالثة و الرابعة.

اجريت التجربة الثانية في غابة سرف سعيد في ولاية القضارف لدراسة تأثير الجروح المنتجة و حجم الشجرة على انتاج الصمغ العربي في شجرة الطلح. تم استخدام تصميم المربعات كامل العشوائية بثلاثة مكررات بنسق تجربة عاملية (٢*٤). العامل الاول كان عدد الجروح المنتجة باربعة مستويات هي ٥ ،٣ ،١، ٠ جروح. العامل الثاني هو حجم الشجرة بمستويين هما اشجار ضخمة(٢٠ -٢٥ سم) و متوسطة(١٥-٢٠سم).استخدم برنامج SAS للتحليل الاحصائي. اوضحت الدراسة تاثير غير معنوي لكل من عدد الجروح و حجم الشجرة علي انتاج الصمغ في شجرة الطلح (احتمالية=٠.٤٥٨ و٠.٢٨٢)). لا توجد فروق معنوية في الانتاج بين اشجار الطلح التي تعرضت لخمسة جروح (٣٠.١ جرام) و تلك التي تعرضت لثلاثة جروح(٢٧.٨ جرام) و جرح واحد (٢٨.٨ جرام)بينما اعطت الاشجار التي لم تتعررض للجرح اعطت ٣١.٢ جرام.وجد ان حجم الشجرة ليس له تاثيرمعنوي في الإنتاج. متوسط إنتاج الصمغ في الأشجار الضخمة كان ٢٦.٢ جرام بينما في الأشجار المتوسطة كان ٣٠.٥ جرام. أوصت الدراسة باستخدام كثافة طق بمستوي خمسة أفرع و استعمال السونكي كآلة للطق في ولاية القضارف.

Table of Contents

List of Abbreviations

FAO	Food Agricultural Organization
GDP	Gum Arabic Domestic Product
IIED	International Institute for Environment and Development
IES	Institute of Environmental Studies
BD	basal diameter
UNDP	United Nation Development Program
FDES	Fuel wood Development for Energy in the Sudan
Red colour	Ax Tool
Black colour	Sounky Tool
Green	3 Branches
Yellow	5 Branches
Blue	7 Branches

List of Tables

List of Figures

List of Plates

CHAPTER ONE
INTRODUTION

1.1. Back ground

Gum Arabic is defined as the dried exudation obtained from the stems and branches of natural strains of *A. Senegal* (L) or closely related species of Acacia *(A. seyal*) family leguminosae (EU, 1996; FAO, 1990).Gum Arabic has been as an article of commerce for over 5000 years and has a wide range of uses in food and pharmaceutical industries, where its stabilizing, thickening and gel forming properties are main physical requirements. It is also used in the manufacture of textile, ink, paper, adhesives, cosmetics, fertilizers, and binder to explosives (Glickman and Sand, 1973). Sudan is the world's largest single producer of gum Arabic and its production accounts for about 80% of the total world exports. Many people in Sudan depend on gum for their livelihood. *A. Senegal* is a multipurpose leguminous tree which occurs in the Savannah belt of Africa and extends over a wide range of ecological zones that differ in Latitude, Altitude, rainfall and soil type. In Sudan it is naturally confined to the gum belt which lies between lat. $10^{ó}$ - $14^{ó}$ where it is found in stabilized sands under rainfall of 280 – 450 and on dark clay soils under rainfall of 500 mm and above (Badi *et al*, 1989). Talh gum is mainly obtained from natural exudation on the stem and the branches of the trees. However, no information is available about the tapping possibility of A. seyal var. seyal for gum production. More than 50 percent of the gum talha comes from Kordofan region (Gum Arabic Company, GAC, 2008).

This amount is collected only from natural forests by local people. The potential production of gum talha in Sudan is very large and studies on the potentiality of A. seyal to produce gum under different stand densities and its response to tapping techniques, and the amount of gum yield per tree per season under different management approaches, are limited. (Abdel magid and Elmahi, (2014)

1.2. Objectives of the study

1. to investigate the effect on gum yield of Acacia *Senegal* and *Acacia. Seyal* in clay soil of Gedarief State.
2. To investigate the effect of tapping tool and tapping intensity (number of tapped branches) on gum yield of *A. Senegal* and A.Seyal in El Rawashda forest.
3. To determine gum yield of *A. Senegal* grown in plantation stands in clay soil of El Rawashda forest.
4. To determine gum productivity of *A.seyal* stand in Saraf Saeed natural forests.
5. To investigate the effect of induced injuries and tree size on gum yield of *A.seyal* in Saraf Saeed Natural forest.

1.3. Hypothesis Of Study

1. Gum Arabic yield of A. *Senegal* in clay soil varies within the type of tapping tools used in El Rawashda forest.
2. The intensity of tapping of *A.sengal* in clay soil affect gum yield of the tree.
3. Induced injuries in the tree of *A.seyal* increase gum yield of the tree in Saraf Saeedforest.
4. Gum productivity of A. seyal is affected by the size of the tree.

CHAPTER TWO

LITERATURE REVIEW

2.1.Definition of Gum Arabic

Gum Arabic is defined as the dried exudation obtained from the stems and branches of natural strains of *Acacia Senegal*(L) or closely related species of Acacia, family *Leguminosae* (EU, 1996; FAO, 1990). Gum Arabic is the oldest and best known of all plant gums and has been used commercially for over 5000years.Sudan is the world, larger producer of gum Arabic. Most of the world's gum Arabic supply comes from Sudan (Ahmed, 2006; Wickens *et al*., 1995).In Sudan more than thirty distinct acacia species are found (El Amin, 1973)., but the great majority of commercial gum come from *Acacia Senegal* and known as gum hashab. The acacia species that are determined closely related to *Acacia Senegal* are *Acacia seyal*, *Acacia polycantha*, *Acacia laeta* and *Acacia meliffera* (Ross, 1979).Gum Arabic is obtained by tapping A. *Senegal* trees in natural stands and/or plantations (Abdelnour 1999; Ballal et al.2005a). However, gum (talha) is mostly obtained from natural *A. seyal* stands and through natural exudation (Abdelnour, 1999; Seif el Din and Zarroug, 1998).).Among awide spectrum of plant exudates, gum Arabic isthe most important and usable gum, it includes both gumsfrom *Acacia Senegal*and *Acacia seyal* trees, which ardistributed in a continuous belt known as the "Gum Arabic Belt". The Sudan is acknowledged as the world dominant leader in gum Arabic production; it contributes to about 95% ofthe total world gum Arabic production (Abdulgadir, 2013).Sudan effectivelycontrols almost over 80% of the world market (Anderson, 1993; GAC, 1996; Forman, 2012; Abdulgadir, 2013). Gum Arabic provides an average of 12percent of the gross domestic product (GDP) of the country, and accounts for about 15.3 percent and 10 percent of thehousehold income of gum producers and other farmers in thegum belt in Sudan, respectively (Elamin and Ballal, 1989; Mahmoud, 2004; Taha, 2006).

2.2. Description of Gum Arabic

Gum Arabic from *A. Senegal* (Fig. 1) is a pale to orange-brown colored solid, which breaks with a glassy fracture. The best grades are in the form of whole, round tears, orange-brown in color and with a matt surface texture; in the broken, kibbled state the pieces are much paler and have a glassy appearance. Inferior grades, and gum from species other than A. Senegal, may not have the characteristic tear shape and are often darker in color.

Figure 3. Gum arabic(Gum Hashab) from A. senegal tree in El Rawasda Resarve forest,(field work 2015.

Gum from A. seyal (gum talha), on the other hand, is more friable than the hard tears produced by A. Senegal and is rarely found as whole lumps in export consignments.

Figure 4.GumArabic from A. Seyal trees in Saraf saeed Forest(field work 2015).

2.3. Gum Arabic belt in Africa

The gum belt occurs as a broad band which extends from Mauritania, Senegal and Mali in the west, through Burkina Faso, northern Benin, Niger, and northern parts of Nigeria, Cameroon and Chad and from the northern Central African Republic to Sudan, Eritrea, Ethiopia and Somalia in the Horn of Africa (Ahmed, 2006). According to the International Institute for Environment and Development IIED and the Institute of Environmental Studies IES (IIED and IES, 1990), the Sudanese gum Arabic belt occurs in Central Sudan, and lies between 10 and 14°N and accounts for about one fifth of Sudan's total area, covering an area where low rainfall interacts with sandy and clay soils. The belt provides important economic activities for rural communities. Rural people live in the gum belt area get their income from several activities which include agriculture, grazing, and forest utilization such as firewood and charcoal production and collection of forest products including gum Arabic.

2.4. Tapping methods

Gum from *Acacia Senegal*(gum hashab) may exude naturally from wounds that may arise from wind damage, attack by termites and beetles or by grazing animals. Commercially, gum hashab is obtained by a process known as tapping.

Tapping for the production of gum Arabic involves removing sections of the bark with a sharp material (e.g. axe) (Germany Fitiwi and Mulugeta Lemenih, 2010). Tapping is practiced to enhance yield quantity and quality. For instance, tapping activities increased gum Arabic yield by 77.42% as compared with untapped trees in Kenya (Wekesa et al., 2009). The branches or bark in different parts are cut using a small axe to break the outer bark horizontally by making a shallow cut about 3.8 cm (1.5 in) wide. The bark is stripped away to form 0.6 to 1.0 m (2 to 3 ft) long wounds (Awouda, 1974).The Axe is moved upwards and downward to cut a strip of the bark. This process is so difficult, time consuming, needs training and experience.

The Axe does not reach the higher branches. Awouda (1973) reported that the use of the axe by an inexperienced tapper results in damaging the wood, hence weakening the tree and making it more susceptible to attack by insects, which might kill it.

An alternative tapping tool, sounky, was developed by The Gum Research Section in El Obeid Research Station, North Kordofan. The tool is composed mainly of an iron part about twenty cm long with a 3-cm long, sharp pointed apex pushed during tapping between the bark and inner cambium, a hook for peeling off the bark and a wooden handle of about 2.5m long. This tool proved to be more efficient and causes less damage to the tree. Tapping generally starts when the trees are three to six or seven years old, with a height of about 1.5-3.7 m and a diameter of five cm. Each ear however trees from seedling Origin are tapped at the age of five years. The trees can be tapped annually up to the age of eighteen years (Dale and Greenway, 1961; Weber and Stoney, 1986).

2.5 Gum Arabic yield

Gum yield is considerably affected by the environment and management practices such as tapping tool and intensity of tapping (Ballal, 1999).Estimate of gum Arabic yield from *Acacia Senegal* showed wide range of variability between individual trees. Tree yield ranges from few grams to two kg/tree with an annual average yield of 250 g (IIED and IES, 1989). ITC (1972) quoted yields per tree ranging from 0.9-2.0 kg.FAO (1978) reported lower estimates of 0.1-0.2 kg per tree or 40–80 kg per Hectare. Badi *et al.* (1989) reported 0.25 kg per tree, equivalent to 100 kgper hectare. Muthana (1988) quoted a yield of 0.225 kg per tree, equivalent to 90 kg per hectare and this yield was calculated on the basis of stocking of400 trees per hectare. Ballal (2002) reported that the variability in gum yield was higher between years.

In most of the years (1994-1999), the average annual yield per pick per tree ranged between 32.2 and 51.9, giving a total annual yield of 198-311 g. Variations in yield estimations per unit area could be attributed to many factors including climate, the type of stand and its management. This wide range of variation in the estimations of gum yield is not reliable for forecasting gum Arabic supplies at the national or international levels. Consequently, gum yield assessment has been and still considered a priority for research. There is a need for measuring gum yieldon per tree basis and within sites variations (Coppen, 1995).Recent studies carried out by Ballal *et al*. (2005b) in Sudan investigated the gum yield variations in natural stands and plantations of *A. Senegal* under different management regimes. In general, the average gum yield from *A. Senegal* in Sudan is about 250 g/tree/season (IIED and IES, 1990). Previous estimates of gum Arabic yield from the same species were found to range from 100-200 g/tree (FAO, 1978).According to Ballal (2002), the type of stand was factored into the above estimates. In this context, he estimated the yield of gum hashab (gum derived from *A. Senegal*) in plantations and natural stands. His estimates ranged from 40.5-87 and 33.0-47.7kg/ha in plantations and natural stands, respectively. Recent studies carried out by Ballal *et al*. (2005b) in Sudan investigated the gumyield variations in natural stands and plantations of *A. Senegal*under differentmanagement regimes. In general, the average gum yield from *A. Senegal*in Sudan isabout 250 g/tree/season (IIED and IES, 1990). Previous estimates of gum Arabicyield from the same species were found to range from 100-200 g/tree (FAO, 1978). According to Ballal (2002), the type of stand was factored into the above estimates. In this context, he estimated the yield of gum hashab (gum derived from *A. Senegal*)

In plantations and natural stands. His estimates ranged from 40.5-87 and 33.0-47.7 Kg/ha in plantations and natural stands, respectively. *A. Senegal*shows promise as a multipurpose species forits range of products and uses: gum Arabic, fodder and wood production, and soil fertility improvement (Raddad *et al.*, 2005). As an N2-fixing species, *A. Senegal*improves degradedlands and nutrient deficient soils (Isaac *et al.*, 2011).

2.6. Main Factors affecting the production of Gum Arabic in Sudan

Most of gum Arabic(gum hashab) produced come from sandy soil within the gum belt of Sudan in Kordofan and Darfur. Production of gum Arabic is affected by many factors including: climatic factors, type of stand, tree size and age, man and animals, tapping techniques and insects and fire.

2.6.1. Climatic factors

Climatic factors: rainfall, temperature and relative humidity affect gum yield significantly. Good rain year usually result in a better gum yield, but if the rain continued to the late of the season this may cause reduction in the yield.

2.6.2. Man and animals

Local people tend to fell mature Acacia Senegal trees for agricultural expansion, firewood and charcoal production to satisfy their energy requirements and to increase their income, these activities lead to reduce production of gum. Grazing and browsing have important effect on gum production. Goats cause great damage to the tree, camels, beside grazing the leaves and branches, may cause considerable loses by eating the gum. Repeated grazing may lead to damage of the seedlings.

2.7. Uses of gum Arabic

The uses of gum Arabic fall into three main areas: food, pharmaceutical and technical. (FAO1995 Rome).Gum Arabic has a wide range of uses in food and pharmaceutical industries, where it's stabilizing, thickening and gel forming properties are the main physical requirements. It is also used in the manufacture of textile ink and paper. Also it is used in baker, meat products, beverages, confectioner adhesives, fertilizers and binder to explosives (Glickman and Sand, 1973).

2.7.1. Food use

In Europe, the food additive number of gum Arabic is E414. a major use for gum Arabic is in confectionery products where it is used to prevent crystallization of sugar or to act as an emulsifier (FAO, 1995).It isalso used in a range of dairy and bakery products (especially as a glaze or topping in the latter). It is used in soft and alcoholic drinks, either as a vehicle for flavouring or as a stabilizer or clouding agent (FAO, 1995).

2.7.2. Pharmaceutical uses

Gum Arabic's use in pharmaceuticals is much less than it once was, and it has been displaced in many of its applications by modified starches and celluloses. However, it still finds some use in tablet manufacture, where it functions as a binding agent or as a coating prior to sugar coating, and it is also used as a suspending and emulsifying agent, sometimes in combination with other gums.

2.7.3. Technical and miscellaneous uses

An important non-food/pharmaceutical application of gum Arabic is inthe printing industry, where it is used to treat offset lithographic plates: as a protective coating

to prevent oxidation; as a component of solutions to increase hydro phobicity and impart ink repellency to the plates; and as a base for photosensitive chemicals. Other technical uses include ceramics, where gum Arabic helps to strengthen the clay, certain types of inks, and pyrotechnics. Use in textiles, paints and adhesives (including the traditional office glue and postage stamps) has decreased to very low levels in recent years, at least in Western markets.(FAO, 1995).

2.8. Gum Arabic production trees

2.8.1 *Gum Arabic from Acacia Senegal tree(gum Hashab)*

Acacia Senegal is a multi-purpose leguminous tree species of ecological and socioeconomic importance and occurs in arid and semi-arid regions. *Acacia Senegal* (L) Wild have four different varieties (DFSC 1990) namely variety *Senegal*, variety *kerensis* Schweinf, variety *rostrata* Brenan, and variety *leiorchachis* Brenan. The variety *Senegal* is the common one in Sudan. It is commonly known in Sudan as 'Hashab'

2.8.1.1.Classification

Family: Fabaceae

Genus: *Acacia*

Species: A**.** *Senegal*

a multipurpose African tree highly valued for centuries for gum Arabic production, which is used in food, pharmaceutical and other industries (Glickman, 1969 ; Anderson and Weiping 1992; ICRAF, 1992; Williams and Phillips ,2000). It also plays a secondary role in agricultural systems restoring soil fertility and providing

fuel wood as well as fodder to livestock (Raddad *et al.*, 2005; Obua *et al.,* 2006; Okunomo and Bosah; 2007 and Isaac *et al.*, 2011).The importance of the tree as an integral component in traditional dry-land agro-forestry is also reported by Raddad (2006)and intercrops well with sorghum and other grasses (Gaafar *et al.*, 2006).

2.8.1.2. Description

Acacia Senegal (L) Willd is described in Sanhi (1968), Vogt (1995) and El Amin (1990) as a shrub or small tree 2 – 12 m tall, with a yellowish or grayish white, rather rough bark and a flat or rounded crown.. *Acacia Senegal* is a legume and deciduous shrub or shrub tree belonging to the sub-genus, *Aculeiferum*. *A. Senegal* is reported to tolerate annual precipitation of 380 - 228 mm, annual mean temperature of 16.2 - 27.8°C, and soil pH of 5.0 - 7.7.This species is a multipurpose African tree highly valued for centuries for Gum Arabic production whichisusedin food, pharmaceutical and other industries(Glickman.1969:Anderson and Weiping ,1992:ICRAF,1992:Williams and Phillips,2000).It also plays a secondary in agricultural system restoring soil fertility and providing fuel wood as well as fodder to livestock(Radd et al ,2005:Obua et al,2006: Okunomo and Bosah: 2007 and Isaac et al, 2011). The importance of the tree as an integral component in traditional dry-land agro- forestry is also reported by Raddad (2006) and intercrops well with sorghum and other grasses(Gaafar et al, 2006).

2.8.1.3. Distribution

A. Senegal var. Senegal is the most widely distributed of the four varieties of Senegal and the most important and best quality source of gum Arabic. It is the only variety found in Sudan, where both natural stands and plantations are tapped.

In Africa it occurs throughout the gum belt but is also found in the arid or semi-arid areas of Tanzania, Zambia, Zimbabwe and Mozambique. It has a limited occurrence in India and Pakistan. The other varieties of A. Senegal have a much more restricted distribution than var. Senegal and provide only very tiny amounts of gum.

2.8.1.4. Ecology:-

Acacia Senegal is highly tolerant to rainfall and temperature variations it grows mainly on sandy soils where early average precipitation falls 280mm and 450mm iso-hyets; but, where the rainfall is less than 150mm the tree stock tends to be scare. Growth clusters of acacia Senegal are also common in clay soils along river beds, and marsh lands of the sahelian zone where the annual rainfall ranges between 600mm and 800mm.The mean Annual temperature in the acacia Senegal belt of the Sahelian zone is between 28and 30degrees centigrade. The growth and development of the tree is, therefore, more dependent on the amount of rainfall and the degree of temperature than on soil type. With deep tap roots and expansive remaining root system, Acacia Senegal has about 40percent of its total biomass laying underground. It is this latter peculiar feature of the tree which is of primary importance in the struggle against both water-born and wind born soil erosion. In addition, Acacia Senegal tree stock, growing in the northern cultivation limits of the Sahelian zone, acts as wind breaks and a buffer zone against desertification. During the long dry periods, however, Acacia Senegal is susceptible to attacks by white ants that damage the roots and causes eventual death of the plant. (Olsson, 1989).

Figure 1. Acacia Senegal tree at El Rawashda forest (gum Hashab) Field work 2015.

2.8.2. *Gum Arabic from Acacia Seyal var .seyal(gum talha*)

2.8.2.1. Classification

A. seyal (figure 1) belongs to the genus *Acacia* Mill., which is one the largest genera within the family *Mimosaceae*.El Amin (1973) reported two infra-specific variations of *A. seyal* Del., widely distributed in Sudan, differentiated on the basis of the presence and absence of the "ant-galls" and the color of the bark. He reported that "ant-galls" is the characteristic of variety *fistula* and the color of its bark is white, while that of variety *seyal* is green or red.

2.8.2.2. Description

The morphological description of *Acacia seyal* var. seyal was revealed by many authors (Dal and Greenway, 1961; El Amin, 1990; Thirakul, 1984; Badi *al et*., 1989). It is medium size tree up to 17 meters high, but 9-10 m is regarded as full-sized over most of its range. Trunk diameter is 25-30 cm. Pole is straight and cylindrical. Lateral branches develop obliquely, forming a flat-topped spreading crown. The most conspicuous feature is the bark which is powdery, smooth, or sparsely flaking in large blackish scales; it displays a range of colors ranging between red, greenish-yellow or orange red, but the predominant one is the reddish. The young branches are rounded, glabrous with numerous reddish glands.

Figure2. Acacia seyal trees in Saraf Saeed forest (gum talha) Field work 2015.

2.8.2.3. Distribution

Acacia seyal is widely distributed in North Africa, in the Sahelian zone from Senegal to Chad, across Sudan in Eastern Africa, from Egypt Southward to Somalia, Kenya, Mozambique and Namibia. It has also been recorded in Syria, Jordan and Sinai. The wide sporadic distribution of A. seyal Del. in Africa, from desert edge in the north through dry and wet savanna in the south suggests a wide range and high tolerance of A. seyal to both drought and high moisture levels.

In Sudan, it has a wide geographical distribution; it extends from the desert to the moist savanna with over 800 mm of rainfall.

In the desert areas the species is restricted to the wettest sites, such as river banks.

A. seyal var fistula is rare in areas west of River Nile. The location of A. seyal community in the Acacia seyal-Banalities woodland savanna is between latitude 10 o and 14 o N and longitude 30 o to 36 o E, when the rain fall increases from 500 mm per annum to less than 700 mm. (Andrews, 1952), (Harrison and, Fadl Allah, 1963), (El Amin, 1990), (Von May dell, 1986) and (Badi al et. 1989).

2.8.2.4.Economic importance

Acacia seyal tree provides economic benefits to local societies these include production of fuel wood, gum, tannins, and forage. The tree is also used for building purposes and as a medicinal plant. The leaves, young branches, flowers and pods are valuable forage grazed by both domestic and wild animals especially during the dry season (El Ghazli, 1998). Local people use poles of medium size with forks for house construction. Branches are used for fencing. The trees with bright yellow flowers and/or green and red bark are used for decoration. The tree is good in soil stabilization and soil fertility as its roots fixes atmospheric nitrogen. In addition, wood fumes and smoke is said to be an effective insect repellent. Acacia seyal (Talh) is widely used as a medicinal plant in Sudan. Bark, leaves and gum are used in local medicine for the treatment of many diseases such as hemorrhage, cold, and diarrheaea. (El Ghazli, 1998). The smoke of A. seyal wood is said to be very effective e in the treatment of rheumatism and also gives the skin nice softness, color and odor (El Amin, 1979).

2.8.2.5. Plant gums

Plant gums are organic substances obtained as exudates from trunks or branches of trees spontaneously or after injury of the bark. The formation of gum in plants was explained by different theories.

Some believed that gum is part of the metabolic process of the plant and it is a physiological product rather than a pathological (Glickman and Sand, 1973). Others relate formation of gum to infection by fungi or bacteria. Some believed that gum is formed as a defense mechanism to protect the wound caused by an injury (Howe's, 1949). The most important plant families that are gum yielder include *Leguminosae, Combretaceae, Sterculiasea and Meliacea.* d Greenway, 1961; Weber and Stoney, 1986).

2.8.2.6. Gum Arabic yield from A. seyal

Unlike the gum of A. Senegal, the commercial use of gum A. seyal is Avery new and exciting development. The exudates of A. seyal has only been commercially available in the United States in 1988. Prior to this it had commonly been used in its raw state as a confection in India. In 1984Importers Service developed the selection, purification and drying techniques to permit the manufacture of spray-dried gum of A. seyal. Since these developments, A. seyal has gained wide acceptance first in industrial applications and more recently in food and pharmaceutical applications for coatings, encapsulation, table ting and as a source of soluble fiber (Importers Service Corporation 2007).A. seyal gum is now available from several other sub-Saharan African countries, notably Chad, where it is called " Gum Friable", and Nigeria, where it is referred to as " Grade No. 2". It is interesting that A. seyal is not harvested in the same manner as A. Senegal. Instead of tapping the tree to develop the gum tear, A. seyal is exuded through naturally occurring breaks or fractures in the tree branches and bark. Historically, the gum would generally go harvested, fracture, fall to the ground and be rendered unsuitable for most food applications in the 1990' s, a method was developed to decolorize the naturally dark A. seyal Gum without damage.

CHAPTER THREE

MATERIALS AND METHODS

3.1. Site Selection

3.1.1. Elrawashda forest

Elrawashda forest is one of the reserved forests of ELfashaga Forest Circle in Gedarif State. It was reserved in 1960. ELRawashda forest reserve lie sat latitude 14˚6' - 14˚24'N and longitude 35˚32' - 35˚49'E, covering an area of about 1212472 feddans in the semi–arid zone in the part of south central clay plains near to the transition between *Acacia mellifra* and *Acacia seyal-balanites* savannah woodland. Soil is dark cracking clay dominating the whole area of the forest. Rainfall range between 200-750 mm per annum. The forest is extremely variable consist of a patch work type, age classes interspersed with open areas. There are several large mechanized farming areas and the reserve is poorly stocked; standing volume/ha amount to eight m 3 .Regeneration is mainly sparse or absent especially of economically most important species A. seyal. There is considerable damage to the forest by illegal felling and lopping of *A. seyal* for livestock fodder (Vink, 1985).

3.1.1.1. Vegetation cover

The following trees and shrubs constitute the vegetation of Elrawashda forest;

1. *Acacia seyal* var. seyal (talha), the dominant tree species. Covering 70 % of the total area of the forest.
2. *Acacia seyal* var. fistula (sufar abyad), in groups and stands especially in the South West part of the forest.

3. *Acacia Senegal* (hashab), found mainly as plantation in 1000 ha and some naturally mixed in talih stand.
4. *Acacia millifera* (kitr), large shrubs dominant on the slopes of the major khors draining towards the Atbara River.
5. *Acacia nubica* (laot), incidental as a small shrub, some pockets in the North part of the forest.
6. *Banalities aegyptiaca* (heglig), small to large, dominant trees, scattered throughout the reserve.
7. *Dicrostachys cinerea* (kadad), shrub or small tree, sporadic, some Pockets scattered throughout the reserve.

3.1.1.2. Climate

Elrawashda lies in the semi -arid zone, with summer rains and warm winters, characterized by rainfall pattern ranging from 400 to 750 mm with an annual average of 600 mm. A study carried out in the Gedarif State reported that the rainfall pattern in the area is characterized by its variability from one year to another (Eltayeb, 1985) Gedarif State experiences a dry season for about eight months of the year. Rainfall in the reserve is markedly seasonal in character; the length of the rainy season fluctuates around the four months between June and September reaching its peak in August. Most of the rains fall from June/July to October/November. Rainfall often comes in the form of heavy downpours during thunderstorms, causing heavy runoff, initiating erosion on sloping and unprotected lands. Elrawashda forest plays an important role in the economy of the different comminutes depending on living standard, needs, and accessibility. The forest supply villager, nomads, and refugees with basic needs such as fuel, building materials, grazing shelter and others (Abu sin and Sammani, 1986).

3.1.2. Saraf Saeed forest

Saraf Saeed forest is located some 36km south of Doka (capital of Gallabt province) in the Eastern state, lat. 13° 20'N and long. 35°50'E. It is within the 800mm rainfall is ohyet. The forest is composed mainly of naturally growing A, seyal and some plantation of A. Senegal, with black cracking clay soil and flat terrain. It is on the edge of the gum belt boundary. It is a good site for *A. seyal* seed collection.

3.2. Study Area

Gedarief State is one of the Eastern Region states of the Sudan, lies between longitudes 33º30 and 36º30 East and latitudes12º40 and 15º40 North. The total population of the State according to 2008 census is 1, 35 million people. The total area of the state is approximately 710 000 km^2. The climate is dry in the North and North West and the rainfall ranges between 100-500 mm during July- October. The eastern and southern parts of the state are wet and rainfall ranges between 500-900 mm per annum, where grasses and natural forests exist (Gedarif state strategic planning committee 2005). Soil is mainly dark cracking clay soil, covering almost the whole area of the state, ten million feddans of which are exploited by rain-fed mechanized farming for cultivating sorghum and sesame. (GSPC, 2005). The total area of the reserved forest is 2530217 feddans, constituting 15% of the state area. Three types of forests are available in Gedarif State; reserved and under reservation forests covering an area of 2 395 807 feddans, community forests with an area of 122 660 feddans and private forests covering 11750 feddans. Shelterbelts established in mechanized agriculture schemes covering an area of 80850 feddans (FNC, Gedarif State 2006).

Table 3.1Annual Rain fall between 2011-2015 Of Gedarif States

Station	Season	Total per (mm)	Average(mm)
Gedarif	2011	501.5	314.0625
	2012	517	73.85714
	2013	570.4	81.48571
	2014	783.8	111.9714
	2015	405.5	57.92857
Al shawak	2011	369.1	92.275
	2012	432.4	108.1
	2013	469.6	117.4
	2014	565.8	141.45
	2015	307.4	76.85
Doka	2011	821.6	205.4
	2012	1015.8	253.95
	2013	507.6	126.9
	2014	836.8	209.2
	2015	839.9	209.975
Al gedumblia	2011	367	91.75
	2012	779.6	194.9
	2013	305.5	76.375
	2014	574.8	143.7
	2015	687	171.75

Source: Mechanize Agriculture Corporation (Gedarief stste2015)

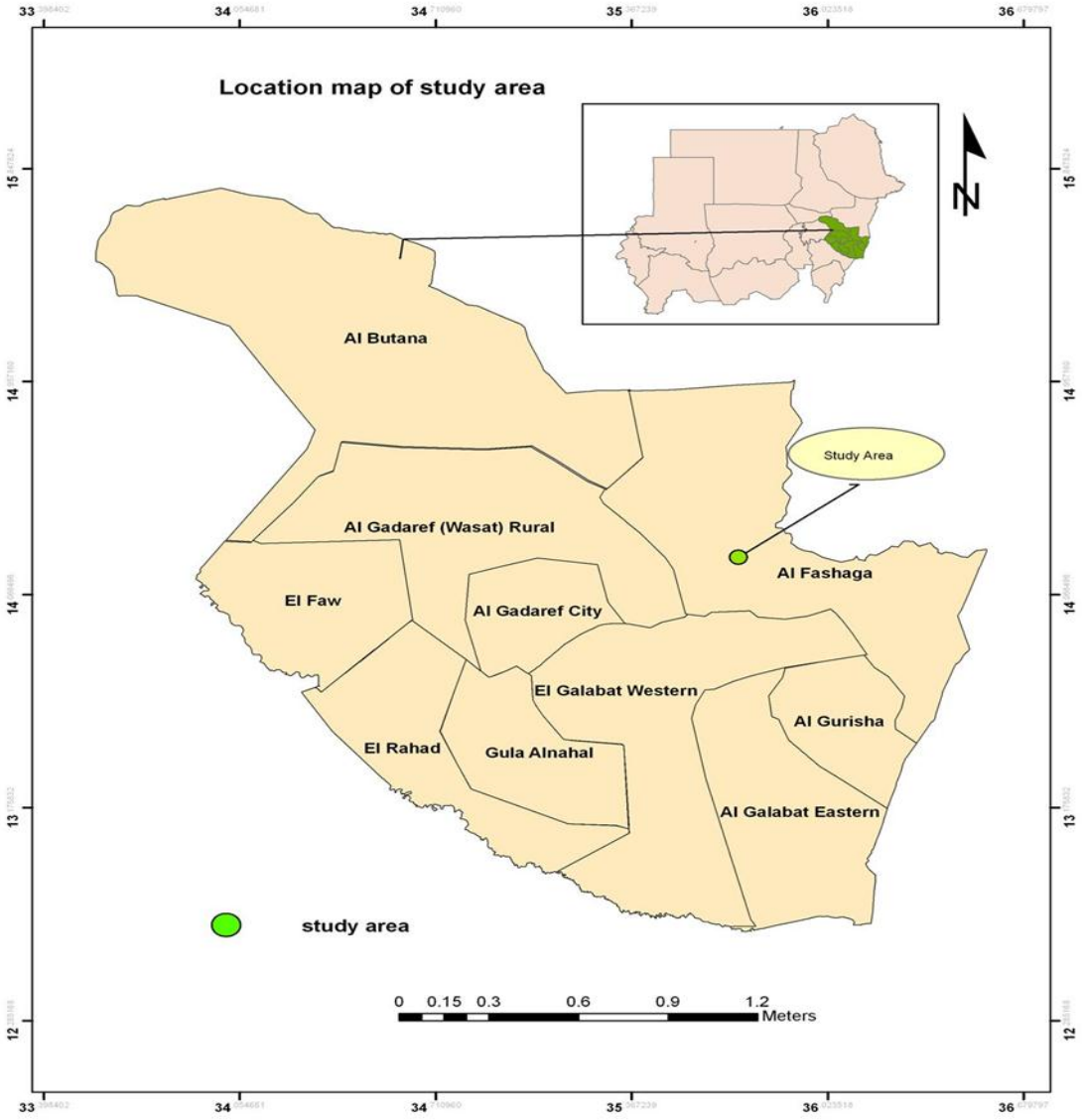

Figure 5: Map of the study area(case study of forest cover change ,Rawashda And Wedcapo 2012)

3.3. Methodology

two experiments each with two factors were carried out at El Rawashda and Saraf Saeed forest to investigate the effect of some tapping techniques on gum Arabic yield in clay soil of Eastern Sudan, Gedarif State. The first experiment was conducted at Elrawashda forest and aimed to investigate the effect of tapping intensity and tapping tool on gum yield of *Acacia Senegal* whereas the second experiment was conducted at Saraf Saied forest and examined the effect of induced injury and tree diameter on gum yield of *Acacia seyal.*

3.3.1. Experiment 1; effect of tapping intensity and tapping tool on gum yield of *Acacia Senegal* in Gedarif State

This experiment was carried out at Elrawashda forest for two consecutive seasons 2014/2015 and 2015/ 2016. Three levels of tapping intensity, namely tapping three, five and seven branches and two tapping tools being axe (fig.4.1) and sounky (fig.4.2) were used. Tree taping for both seasons commenced in 15th of November and six weeks later the first picking was conducted in the second of January. Four pickings were made with two weeks interval. Collected gum was air dried and weighed in grams for each picking using two decimal sensitive balance. A factorial experiment (3×2) arranged in a randomized complete block design with three replicates was used. The first factor was tapping intensity with three levels namely tapping seven, five and three branches and the second factor was tapping tool with two levels, being axe and sounky. Five trees were tapped in each experimental unit and hence the number of tapped trees was 120 (3*2*5*4). Analysis of variance was conducted using SAS statistical software version 9. (SAS Institute Inc., 2003). Duncan Multiple Range Test was used to separate between means.

3.3.2. Experiment 2: Effect of induced injury and tree size on gum yield of *Acacia seyal*

This experiment was carried out at Saraf Saeed forest to study the effect of induced injury and tree size on gum yield of A. seyal. A factorial (2×4) experiment was carried out. The first factor comprised two levels of tree size: large and medium. The second factor constituted four levels of induced injury being: 1, 3 and five injuries, besides the control. Injuries were made on the main stem (figure 5). A randomized complete block design (RCBD) was used with four replications. Tapping was carried out on the 1st of November, then first and subsequent picks were done in interval of one month. After having been dried at room temperature for 48 hours, the collected gum was then weighed and recorded. Analysis of variance was conducted using SAS statistical software version 9. (SAS Institute Inc., 2003). Duncan Multiple Range Test was used to separate between means.

Figure 6: Injuries made on A.seyal tree at Saraf Saeed reserved forest(field work2015)

CHAPTER FOUR

RESULTS AND DISSCUSIONS

4.1 Results

4.1.1 The effect of tapping intensity and tapping tool on gum yield

4.1.1.1 Gum yield Of Acacia Senegal

Results of analysis of variance on mean gum yield per tree presented in Table 4.1 and Table 4.2

Table: 4.1 ANOVA Table on mean gum yield per tree of *Acacia Senegal* 2014/2015

Source Of Variation	Df	SS	MS	F value	P
Intensity	2	108558	5279	5.90	0.004
Tool	1	5967	5967	6.67	0.011
Intensity*tool	2	1405	702	6.78	0.459

Table: 4.2 ANOVA Table on mean gum yield per tree of *Acacia Senegal* 2015/2016

Source of variation	Df	SS	MS	F value	Pr
Intensity	2	14764	7382	9.9	0.001
Tool	1	6841	6841	9.1	0.003
Intensity*tool	2	889	444	.6	0.553

for the two seasons under study showed insignificant interaction effect between tapping intensity and taping tool in both seasons 2014/15 and 2015/16 (p= 0.459 and 0.553) respectively.

The effect of tapping intensity on mean gum yield per tree was found to be significant during both seasons (p =0.004 and p =0.0 01) (Table 4.1 and Table 4.2).

During the first season gum yield produced under seven branches tapping intensity (62.1 g) is not significantly different from that produced under five branches level (56.4 g) (Table 4.3). However, the three branches intensity level differed significantly from both seven and five intensity levels.

Table: 4.3 Effect of tapping intensity and tapping tool on mean gum yield (g) per tree of *Acacia Senegal* 2014/15 and 2015/16 in El Rawashda forest

Treatments	Gum yield per tree	
Tapping Intensity	2014/15	2015/16
7 branches	62.1 a	59.5 a
5 branches	56.4 a	52.1 a
3 branches	33.3 b	29.4 b
Tapping Tools		
Sounky	58.6 a	55.7 a
Axe	42.5 b	38.2 b

Means in the same column followed by the same letter are not significantly different using Duncan Multiple Range Test

During the second season 2015/16 gum yield followed the same trend. The seven and five branches levels of tapping intensity were not significantly different from each other but both of them are significantly different from the three branches level (Table 4.3). The effect of tapping tool on gum yield per tree was observed to be significant (p =0.011and 0.003) for the two seasons (Table 4.1 and Table 4.2). Trees tapped with sounky gave significantly higher mean gum yield (58.6 and 55.7 g) than those tapped with the axe (42.5 and38.2 g) (Table 4.3) in the two seasons respectively. During the first season 2014/15 trees tapped with the sounky under seven branches level produced less gum yield (61.1 g) than those tapped during the second season 2015/16 (65.1 g) (Table 4.4).

Table: 4.4 *Acacia Senegal* mean gum yield (g) per tree in relation to tapping intensity and tapping tool 2014/15 and 2015/16 in El Rawashda forest

parameter	2014/15		2015/16	
	Tapping tools		Tapping tools	
Tapping intensity	Sounky	Axe	Sounky	Axe
7 branches	61.1	50.4	65.1	53.3
5 branches	60.2	49.4	59.6	44.6
3 branches	46.0	18.6	42.4	16.4

Trees tapped with the axe at the three level intensity during the first season gave near to that obtained in the second season (18.6 g and 16.4 g respectively).The combination of the sounky tool with seven branches intensity gave higher mean gum per tree (65.1 g), whereas using the axe under three level intensity gave lower gum yield (16.4 g) Table 4.4).

The ANOVA results of gum Arabic productivity of the two seasons 2014/15 and 2015/16 (combined analysis) presented in table 4.5.

Table 4.5. ANOVA Table on mean gum yield per tree of *Acacia Senegal* (combined analysis for two seasons)

Source of variation	Df	SS	MS	F value	P
Intensity	2	26684	13342	13.7	0.001
Tool	1	11203	11203	11.5	0.008
Season	1	244.8	244.8	0.25	0.618
Season*Intensity*tool	2	4504	643	0.73	0.645

revealed that the effect of season was insignificant (p=0.618). It also showed insignificant interaction effect (p=0.645). The higher average gum yield per tree (62.2 g) was obtained when tapping with the sounky at the seven branches level, and lower yield (17.5 g) was produced when tapping with the axe at the three branches intensity level (Table 4.6).

Table: 4.6*Acacia Senegal* mean gum yield (g) per tree in relation to tapping intensity and tapping tool (combined analysis for two seasons 2014/15 and 2015/16

Parameter	tapping tool	
Tapping intensity	Sounky	Axe
7 branches	62.2 (39.3)	52.2(27.0)
5 branches	61.5(28.8)	51.2(43.0)
3 branches	44.4(25.2)	17.5(13.8)

Standard deviations are given between brackets

The effect of tapping intensity on gum yield combined for the two seasons was illustrated in figure (7). The higher gum yield (57.2 g) was obtained under seven branches intensity and the lower (30. g) was obtained with three branches level. The effect of type of tool on gum yield averaged for the two seasons was illustrated in figure (8). Tapping with sounky gave significantly higher gum yield (56.2 g) than hat produced with axe (40.3 g).

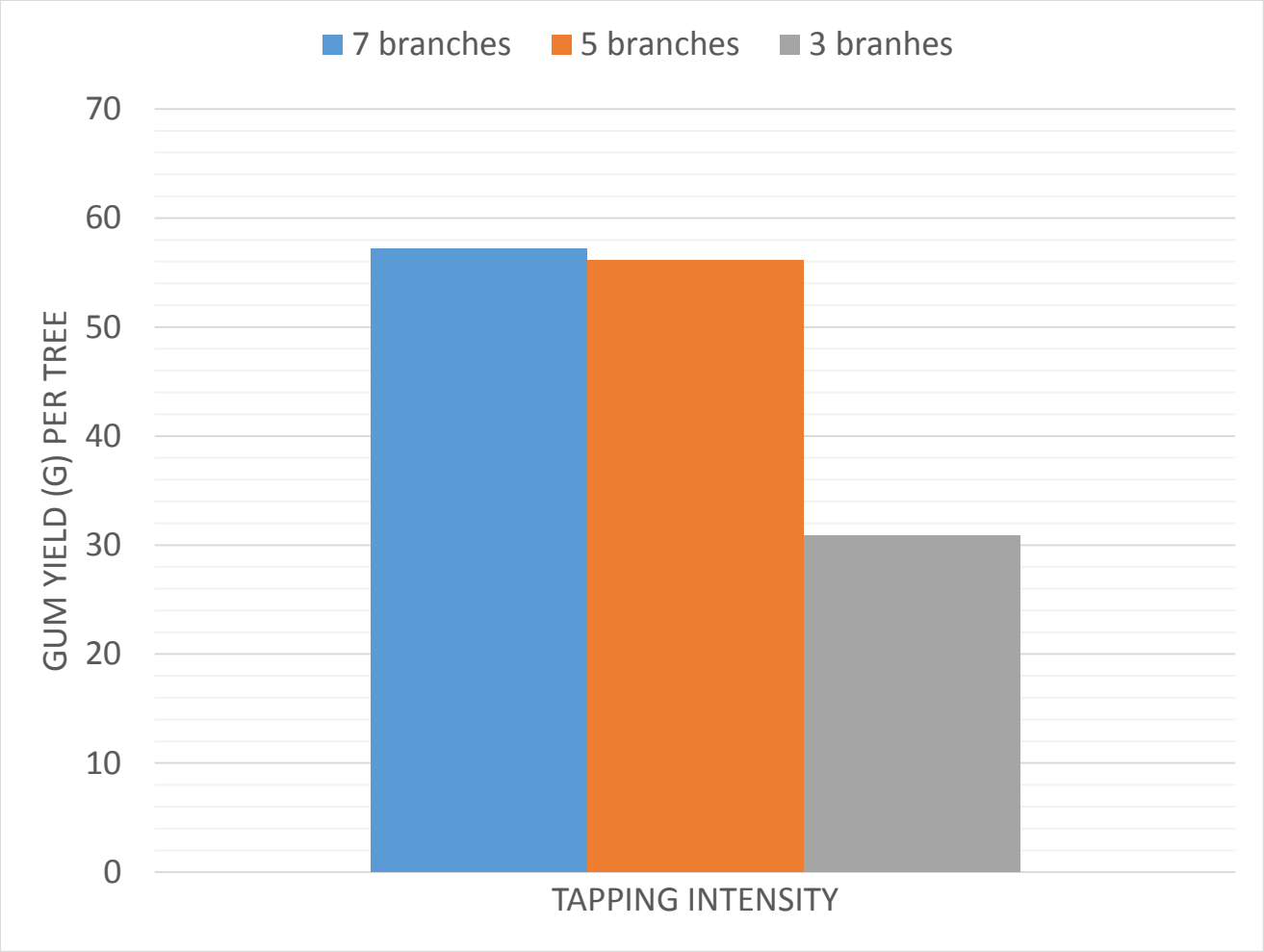

Figure 7. The effect of tapping intensity on gum yield of A. Senegal (combined analysis over two seasons)

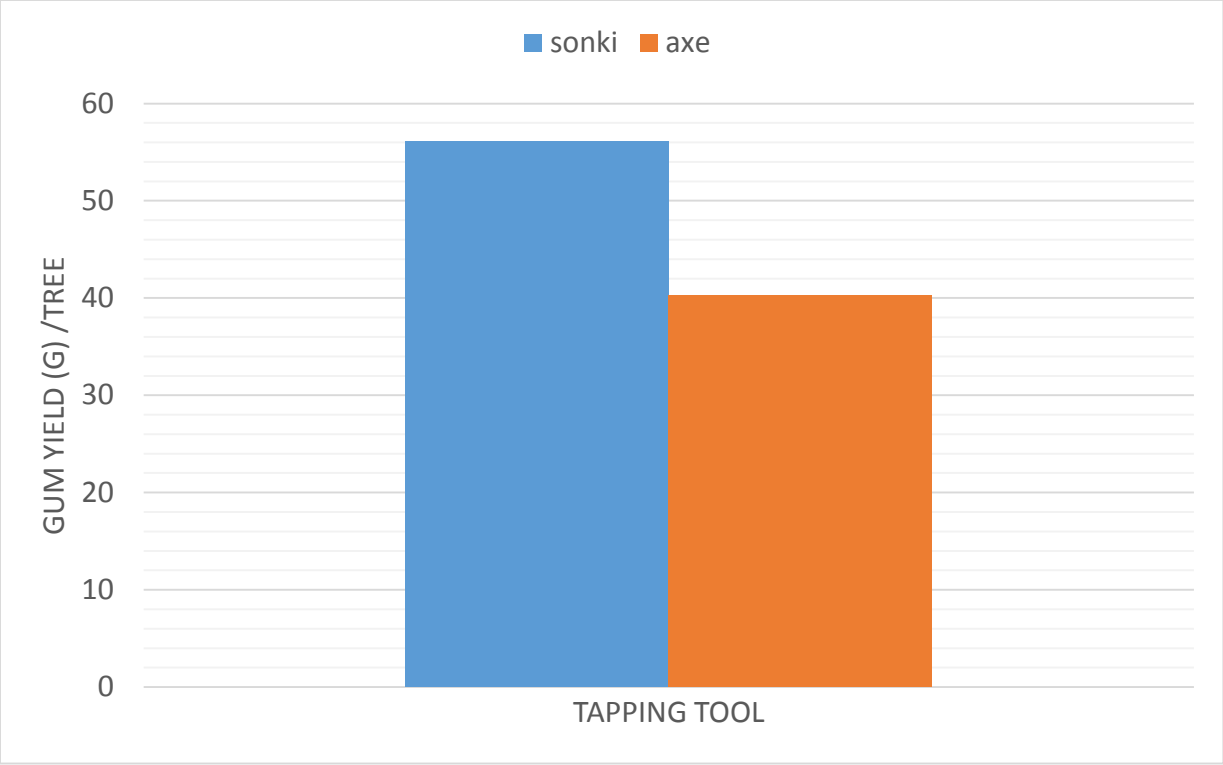

Figure 8. The effect of tapping tool on gum yield of A. Senegal (combined analysis over two seasons)

4.1.1.2 Gum yield per picking

ANOVA results on mean gum yield per picking of the first season 2014/15 showed significant effect of both tapping intensity and tapping tool p(≤ 0.001) for all pickings. No significant difference was found among pickings at intensity levels of seven and five branches. However, in all pickings, the three branches level differed significantly from both other levels (Table 4.7). The first picking at seven branches level gave the higher yield (21.7 g) whereas the fourth picking at level three branches gave the lowest (6.5 g) (Table 4.7).

Table: 4.7Mean gum yield per picking (g) of *Acacia Senegal* in relation to tapping intensity and tapping tool 2014/2015 in El Rawashda forest

Treatments	Gum yield (g)			
Intensity	1th picking	2nd picking	3rd picking	4th picking
7 branches	21.7 a	12.8 a	14.5 a	13.1 a
5 branches	17.8 a	12.3 a b	14.1 a	12.2 a
3 branches	9.2 b	8.1 b	9.5 b	6.5 b
Tapping tool				
Sounky	17.2 a	13.6 a	14.9 a	12.9 a
Axe	15.4 a	8.5 b	10.4 b	8.2 b

Means in the same column followed by the same letter are not significantly different using Duncan Multiple Range Test

The effect of tool type was found to be significant in all pickings except in the first picking. The higher gum yield (17.2 g) was obtained in the first picking whereas the fourth and the second pickings gave 8.2 and 8.5 g respectively (Table 4.7).

During the second season 2015/2016 analysis of variance results also showed significant effect of tapping intensity and tapping tool on gum yield per picking ($\leq$ 0.005). In all pickings the seven branches intensity level is not significantly different from the intensity of five branches (Table4.8).

Table: 4.8 Effect of tapping intensity and tapping tool on mean gum yield (g) per picking of *Acacia Senegal* 2015/2016 in El Rawashda forest

Treatments	Gum yield (g)			
Intensity	1th picking	2nd picking	3rd picking	4th picking
7 branches	19.6 a	12.8 a	13.2 a	11.6 a
5 branches	15.7 a	12.3 a b	11.6 a	10.6 a
3 branches	7.3 b	8.1 b	6.9 b	5.7 b
Tapping tool				
Sounky	16.1 a	14.9 a	13.3 a	11.4 a
Axe	8.5 b	13.4 a	7.9 b	7.1 b

Means in the same column followed by the same letter are not significantly different using Duncan Multiple Range Test

The first picking gave the higher gum yield (19.6 g) at the seven branches intensity level whereas the fourth picking gave the lowest (7.1 g) at the three level (Table 4.8) except in the second picking the tool type effect was observed to be significant (Table4.8).

Trend in gum yield (g/picking) in relation to season (figure. 9) showed that maximum yield was obtained in the second picking, followed by a steady drop in the third and the fourth picking.

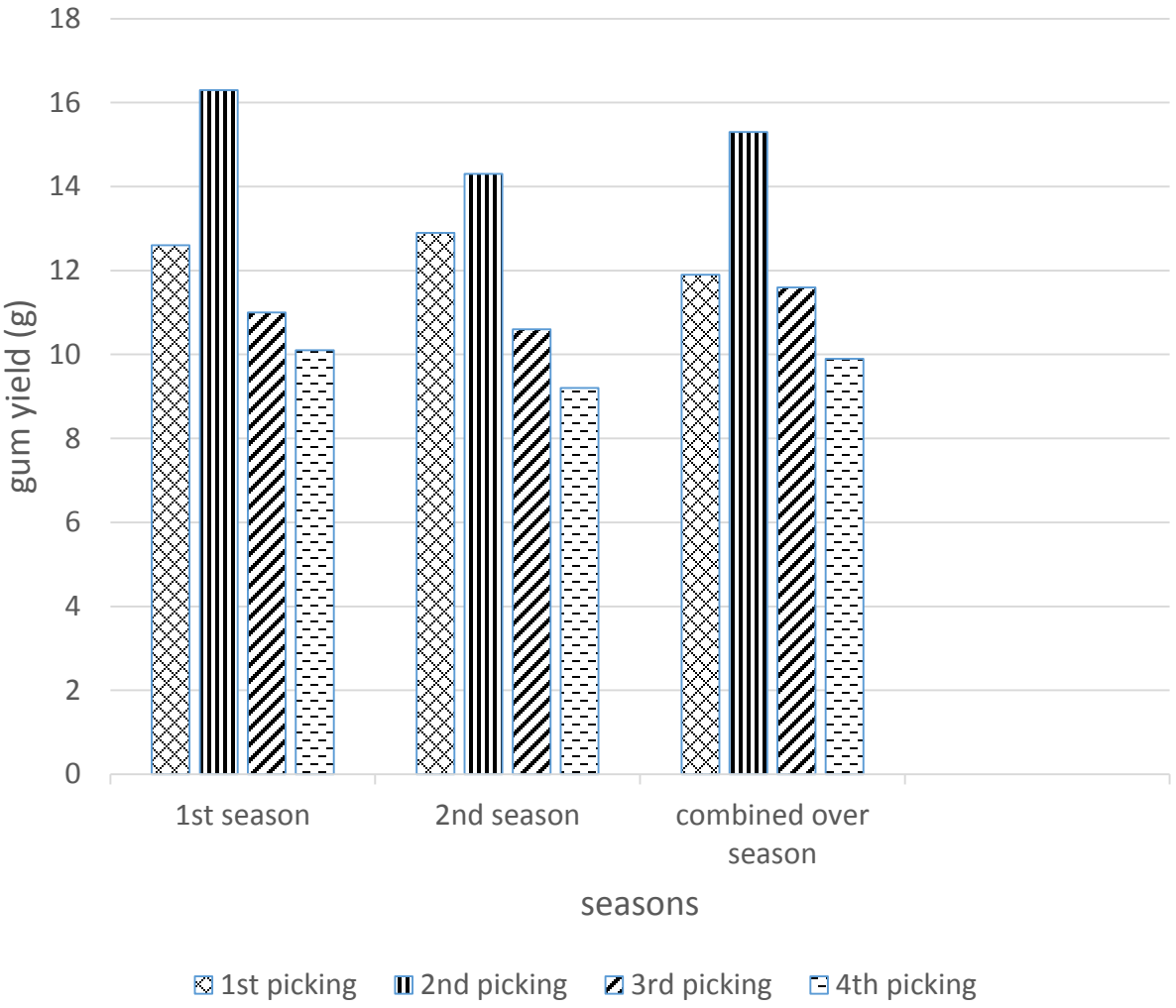

Fig. 9 Trend of gum Arabic yield (g/ picking) of *A. Senegal* in relation to season in Gedarif State

4.1.2 Effect of induced injury and tree size on gum yield of Acacia seyal

Results of analysis of variance on mean gum yield per tree of A. seyal were given in table 4.9.

Table: 4.9 ANOVA Table on mean gum yield per tree of *Acacia seyal* in Saraf Saeed forest

Source of variation	df	SS	MS	F value	Pr
Tree size	1	534.55	534.55	1.33	0.2521
Injuries	3	1054.19	351.38	0.87	0.4581
Size*injury	3	752.39	250.79	0.62	0.6023

The effect of both tree size and number of induced injuries was found to be insignificant (P = 0.252 and 0.458 respectively).

A seyal trees subjected to five injuries produced the higher gum yield (30.8 gram) whih is not significantly different from yield of trees subjected to one and three injuries which gave gum yields of 28.8 and 27.8 grams respectively (Table 4.10). Gum yield of the control trees(0 injuries) (31.2 grams) was higher than the yield of trees injured one and here times, but there is no significant difference between them (Table 4.10).

Table: 4.10 Effect of injury and tree size on mean gum yield (g) per tree of *Acacia seyal* in Saraf Saeed forest

Treatments	gum yield per tree
No. of injuries	
5injuries	30.8 a
3 injuries	28.8 a
1 injury	27.8 a
0 (control)	31.2 a
Tree Size	
Large	26.2 a
Medium	30.5 a

Means in the same column followed by the same letter are not significantly different using Duncan Multiple Range Test.

Table: 4.11 Acacia *seyal* mean gum yield (g) per tree in relation to no. of injuries and tree size

Parameter	Tree size	
No. of injuries	Large	Medium
injuries	24.4 (12.5)	37.2(23.2)
injuries	23.6(14.6)	23.9(15.8)
injury	27.1(20.1)	28.6(24.2)
0 (control)	30.0(22.2)	32.5(24.1)

Standard deviations are given between brackets

4.2. Discussions

Variations in the response of *A. senegl* to different treatments refleted significant effect of tapping intensity and tapping tool on total gum yield (g/tree) and gum yield (g/picing).The average annual gum arabic yield per tree from acacia senegal is very variable ranginging from few grams to 10 kg. (FAO,1978).Previous estimates of gum Arabic yield from the same species were found to range from 100-200 g/tree (FAO, 1978). Ballal *et al*. (2005) attributed the variation on gum yield per tree to variation in environmental factors, mangement practices such as methods of tapping, date of tapping, and tapping intensity, and probably to to the variations in the genetic makeup of the trees. Gum yield per tree increased significantly with increase in tapping intensity from three, five to seven branhes giving 30.9., 56.4 and 57.2 grams respetivvely. The 45.1% increase in total gum yield (g/tree) with increase in intensity level from three to seven branches is in line with the finding of Ballal (2005) who reported possative correlation between tapping intensity and gum yield of *A. senegal* in sandy soils of Kordofan. the finding is also suported by Tadese, et.al (2016),who worked on gum productivity of *A. senegal* in Ethiopia who reprted increase in gum yield per tree with increase in number of tapping spots. However, on the contarary, kamal and Gebauer (2006), reported insignificant effect of intensity after tapping *A.seyal* trees in Western sudan. Intensive tapping of *A.senegal* tree may lead to over-exploitation, loss of vigor and evetually deterioration of the tree. Non significant effect between tapping intensiy of 7 and 5 branches intensity levels could be an indicator for the ipmorance of further studies for detrmination of the optimum tapping intensity in relation to growth parameters of *A.senegal* in sudan.

Sounky is the suitable tool released and recommended by the Agicultural Research Corporation fo tapping A. senegal trees in Sudan. The significant increase in gum yield of *A.sengal* due to tapping with sounky agree with the finding of Ballal *et al*, (2005a) who reprted higher gum yield for trees tapped with sonki compared to those tapped with the axe. Omer (2008), also repoted increase in gum productivity of *A. polycantha* after tapping with the sonki. However,on the other hand, El Nour *et.al* (2015),. Irrespective of tapping intensity and type of tool gum yield (g/picking) of A. Senegal followed a clear trend: the threshold in gum yield was reached in the second picking, followed by a steady decrease in the third and the fourth pickings. Previous findings (Ballal *et al*, 2005b)) based on eight years data have showed a similar trend with considerable increase in yield in the second pick followed by steady drop in subsequent picks.. The insignificant effect of induced injury on gum yield observed in this study is in line with the findings of Hinet 2007 who studied gum yield of A. seyal in relation to diameter. The negative effect of induced injury found in the study agree with the finding of Fadl and Gebauer, 2004 who reported insignificant effect of tapping on gum yield of A. seyal.

CHAPTER FIVE

CONLUSIONS AND REOMMENDATIOS

5.1 Conclusions

In the present investigation, gum yield of *Senegal* tree in clay soil was significantly affected by tapping intensity (number of branches tapped per tree) and tapping tool. Considerable increase in total gum yield (g/tree) and gum yield (g/picking) was obtained with increase in tapping intensity. Variations on total gum yield (g/tree) between 7 and 5 tapping intensity was observed to be insignificant, accordingly, tapping 5 branches of *A. Senegal* is recommend. However, more research work is needed to come to the optimum number of branches to be tapped. *A. Senegal* trees tapped with the sounky produced significantly more gum yield than those tapped with the traditional axe. This Tool can be used to improve gum Arabic production in clay soil and hence increase households' income in rural communities.

Considering gum yield per tree of A. seyal in Gedarif State the study revealed that gum yield is not significantly affected by injuries made on the tree.

5.2 Recommendations

Research on the response of A. Senegal to tapping techniques in gum productivity proved positive relationship with consideration to the findings of this research the followings could be recommended aiming to improve gum Arabic productivity from a, Senegal and A. seyal:

- Tapping five branches of A. *Senegal* plantations in Gedarif State.
- Use of soukny as a tool for tapping A. Senegal trees instead of the axe which, under improper use. may lead to the damage of the tree.
- Extension programs should be implemented in Gedarif state to raise the awareness of local people on how to manage tapping process of the Gums.
- More research to be conducted on different techniques to improve A.seyal gum production.

REFERENCES

Abuelgasim, Z.H. 2002. Some variations in Acacia seyalDel.var. seyal (Brenan) in Sudan in relation to the color of the bark . PhD Thesis submitted the Khartoum university

Ali, E. Y. (2006). Yield potential of *Acacia seyal* Del. variety seyal in relation to growth parameters, methods and position of tapping. Master Thesis. Faculty of Natural Resources and Environmental Studies, University of Kordofan.

Anderson, D. M. W., & WEIPING, W. (1992). Gum Arabic (Acacia Senegal) from Uganda: Characteristic NMR Spectra, amino acid compositions, and gum/soil cationic relationships. *International tree crops Journal*, *7*(3), 167-179.

Anderson, D.M.W. and Weiping, W. 1994 The Tree Exude Gums Permitted in foodstuffs as emulsifiers, stabilizers and thickeners. Chemistry and Industry of Forest Products, 14

Awouda, H.M. (1974). Production and Supply of Gum Arabic. Khartoum. P.5.Awuoda, E. H. M. (2000). Production and commercialization of gum Arabic. Workshop on Management of Trees for Farmland Rehabilitation and Development, Khartoum, Sudan.

Badi, K.H; ELHori, A. and Bayoumi, A.A. 1989 . The Forests of the Sudan . Forest Department. Khartoum, Sudan.

Ballal, M. E. (2002). Yield trend of Gum Arabic from Acacia Senegal as Related to some Environmental and Managerial factors. Ph.D. Thesis. Faculty of Forestry, University of Khartoum.

Ballal, M. E., El Siddig, E. A., Elfadl, M. A., and Luukkanen, O. (2005b). Relationship between environmental factors, tapping dates, tapping intensity and gum arabic yield of an *Acacia senegal*plantation in western Sudan. Journal of Arid Environments, 63, 379–389.

Ballal, M. E., El Siddig, E. A., Elfadl, M. A., and Luukkanen, O. (2005a). Gum Arabic yield in differently managed *Acacia Senegal* stands in western Sudan. Agro forestry Forum, 63, 237–245.

Ballal, M.E, El Siddig, E.A, Elfadl MA, Luukkanen . O (2005a). Gum arabic yield in differently managed Acacia senegal stands in western Sudan. Agro-forest Syst 63(3):237–245.doi:10.1007/s10457-005-4162-x.

Chikami, B.N., Casadei, E., Coppen, J.J.W., Abdel Nour, H.O. and Ce, D. (1997). A Reivew of production, Markets and Quality Control of Gum Arabic in Africa. FAO. Technical Cooperation Programme. TCP/RAF/4557. Rome.

Chiveu, J.C, Dangasuk, O.G, Omunyin, M.E, Wachira, F.N (2009). Quantitative variation among Kenyan populations of Acacia senegal (L.)Willd for gum production, seed and growth traits. New Forests, DOI 10.1007/s11056-008-9128-1.

Dale, I.R. and Green way, P.J. 1961.Kenya Trees and Shrubs. Buchanans Kenya Estates, Nairobi. Pp 653.

Dry lands, 1: 186-193.

Duke, J.A. 1983. Acacia seyal Del. Hand Book of Energy Corporation . Unpublished.

El Khalifa, M.D, Samani, M.O.E, Abdel Nour, H.O (1989). Gum Arabic rehabilitation in The Republic of the Sudan. Report No.1 (2), Institute of Environmental Studies, University of Khartoum, Sudan.

ElAmin, H.M. 1973. Sudan Acacias. Forest Research Institute. Bulletin No: 1. Khartoum. Sudan.

ELAmin, H.M. 1979. Geographical Distribution of the Sudan Acacias. Sudan Forest Administration . Forest Research Institute . Bulletin No 2:1-22.

ElAmin, H.M.1981. Trees and shrubs of the Sudan . Ph.D. Thesis, Faculty of Science, University of Khartoum. Sudan.

ELGhazali, G.E.1998. The Medical and Aromatic Plant of Khartoum State National Research Centre , Medicinal and Aromatic Research Institute, Khartoum, Sudan .

ELsheikh, A.E. 1987. Some notes on Acacia seyalDel.Var. seyal Brenan (Talh). Sudan Silva No 26 Vol VI. Eltayeb (1985).

Eltohami, M.S. 1995. Case study on medicinal and aromatic plant in the Sudan. Khartoum medicinal and aromatic plant research institute.

FadAlla, B.M. 1963. A study of Acaciaseyal Del. In Sudan Msc Thesis, University of Khartoum.

FAO (2004). Exudates Gum 2 IN Non-wood Forest products for rural income and sustainable forestry. FAO, Rome.

FAO.2000a.Development of Gum Arabic production and marketing Asocio economic survey of Gum Arabic producer and trader.

FDA (2002). Baseline survey on gum arabic. Federal Department of Agriculture, Abuja, Nigeria, pp. 4-10.Forests National Corporation Gedarief State 2006)

Gaafar, A.M, Salih, A.A, Luukkanen, O, El Fadl, M.A, Kaarakka. V (2006) . Improving the traditional Acacia Senegal-crop system in Sudan: the effect of tree density on water use, gum production and crop yields Agro-forest Syst 66(1):1–11. doi:10.1007/s10457-005-2918-y. Gedarief profile2010 UNDP

Gedarief state Strategic Planning Committee, 2005) Gedaref Wikipedia, 2011)

Glicksman, M (1969). Natural Plant Exudates. Academic Press, Inc., New York.

Harmand, J.M, Ntoupka. M, Mathieu. B, NjitiForkong C, Tapsou J.C, Bois J, Thaler P, Peltier. R (2012). Gum arabic production in Acacia Senegal plantations in the Sudanian zone of Cameroon: effects of climate, soil, tapping date and tree provenance. Bois For Trop 66(311):21–33.

Hineit, B. M. (2007). Effect of type, time of tapping and tree size of *Acacia seyal*var.seyal on the production of gum talha in Rawashda forest, Gedarif State, Sudan. Master Thesis. Faculty of Forestry, University of Khartoum

IIED/IES (1990). Gum Belt Rehabilitation in the Republic of Sudan, Stage 1. Main Report and Recommendations for Action. By: International Institute for Environment and Development, London, England and Institute of Environmental Studies, University of Khartoum, Sudan.

Isaac, M. E., Harmand, J. M., Lesueur D., Lelon .J (2011).Tree age and soil phosphorus conditions influence N2 fixation rates and soil N dynamics in natural populations of *Acacia senegal*. Forest Ecology and Management, 261: 582-588.

Jamal, A. Huntsinger. L (1993). Deterioration of a sustainable agro-silvo-pastoral system in the Sudan: the gum gardens of Kordofan. Agroforest. Syst., 23: 23-38.

Joint FAO/WHO Food Standards Programme Codex Alimentarius Commission. Twenty-third Session Rome, Italy, 28 June - 3 July 1999. Report of the Thirty-First Session of the Codex. Committee on Food Additives and Contaminants. The Hague, the Netherlands, 22-26 March 1999

Mahgoub, S.M and DafAlla, T. 1996. Acacia seyal Del varseyal Brenan; Seed Handling and Silvicultural Operations. NTSC. Publication No10 Khartoum, Sudan.

Mahmaud,A.E; AbdelazimY.Abdelgadir; Ashraf M.A.Abdalla and Atif AL Hady 2007. Wood anatomy of Acacia seya l var. seyal.Wood anatomy series of the main tree species in northern Sudan . Faculty of Forestry. University of Khartoum.

Maundu, P.M, Ngugi, G.W, Kasuye ,H.C (1999).Traditional food plants of Kenya. Nairobi, Kenya.

ME, A. S., & El Sammani, M. O. (1986). Socio-economic aspects of integrated resource management, with special reference to the forest resources of Kassala Province, Eastern Region. The case of Rawashda and Wad Kabu forests.
NAFTA. 1994. A quick quid to useful nitrogen fixing trees from around the world. Accessed at www.winrok.org . in May(2007).

NAS. (1979). Tropical legumes: Resources for the future. Report of an Ad Hoc Panel of the Advisory Committee on Technology Innovation, Board of Science and Technology for International Development, Commission on International Relations, National Research Council. National Academy of Sciences, Washington, D.C., USA. pp 331.

NON-WOOD FOREST PRODUCTS Gums, resins and latexes of plant origin byJ.J.W. Coppen FAO.Rome,1995.Non-Wood Forest Products series. No. 2. 62 pp. Rome: Food and Agriculture Organization.

Obeid M, Seif Eldin .A (1970). Ecological studies of the vegetation of the Sudan. Acacia Senegal (L.) Willd. and its natural regeneration. J.Appl. Ecol. 7: 507-518.

Obua J, Agea ,J.G, Namirembe S, Egadu. S, Mucunguzi. P (2006). The potential of Acacia Senegal for dry land agro-forestry and gum Arabic production in Uganda. J.

Okunomo K, Bosah, B.O (2007). Germination Response of Acacia Senegal (Linn) Seeds to Various Pre-sowing Treatments in the Nursery. Agricultural Journal, 2:681-684.

Osman , M. E (1993) . Characterization and fractionation of the gum from Acacia Senegal. Ph.D. thesis, Salford University, United Kingdom. 1993.

Raddad, E. Y., Salih A. A., El Fadl M. A., Kaarakka V., Luukkanen O.,(2005). Symbiotic nitrogen fixation in eight *Acacia Senegal* provenances in dry land clays of the Blue Nile Sudan estimated by the (15)N natural abundance method. Plant and Soil, 275: 261-269.

Sareo COPPEN, J.J.W. and HONE, G.A. (1995) Gum Naval Stores : Turpentine and Rosin from Pine Resin.

Sayeda, A. A. Khalil, H. A. El Atta and I.M. Aref (2011) . Increased gum Arabic production after infestation of *Acacia Senegal* with *Aspergillusflavus*and *Pseudomonas pseudoalcaligenes*transmitted by *Agrilusnubeculosus* . African Journal of Biotechnology Vol. 10(37), pp. 7166-7173, 20 July, 2011 Available online at http://www.academicjournals.org/AJB DOI: 10.5897/AJB10.2619 ISSN 1684–5315 © 2011 Academic Journals .

Seif el Din, A. G., and Zarroug, M. (1998). Production and commercialization of gum Arabic in Sudan. In FAO (editor), International conference on domestication and commercialization of non-timber forest products in agro forestry systems. Non-Wood Forest Products 9. Held on 19-23 February 1996: Nairobi, Kenya. Rome: FAO.

Seif El, Din. A (1995). Gum Arabic Production in Sudan, Paper Presented at the Agricultural Insurance Workshop in Sudan Sheikan Insurance and Reinsurance Co. Ltd., Sudan p. 15.Vink, 1985.

Verbeken ,D , Dierckx. S, Dewettinck. K (2003). Exudates' gums: occurrence, production, and applications. Appl. Microbial. Biotechnol.63: 10-21.

Wekesa C, Makenzi, P.M, Chikamai ,B.N, Luvanda, A.M, Muga, M (2010). Traditional Ecological Knowledge Associated with Acacia Senegal (Gum Arabic tree) management and Gum Arabic Production in Northern Kenya. International Forestry Review. 12(3):240-246.

Wekesaa , B.N ,Chikamaib, G.M, Muturic, J.K, Lelonc, M.O, Mugac , Luvandad.(2015) . Gum Arabic Production Potential of Naturally growing Acacia Senegal varieties in Kenyan Dry lands. Octa Journal of Environmental Research ,(Oct.Jour.Res .) ISSN:2321-3655 http://WWW.sciencebeingjournal.com.

Williams, P.A, Phillips, G.O (2000). Gum Arabic. In: Phillips, Williams PA (Eds.), Handbook of Hydrocoll. CRC Press, Boca Raton FL, pp. 155-168.