American Journal of Agriculture and Forestry
2025, Vol. 13, No. 3, pp. 152-168
https://doi.org/10.11648/j.ajaf.20251303.12

Research Article

Gum Arabic Research in Sudan During the Period 2000-2025 a Review Paper for Some of Research Activities During the Period 2000-2025

Kamal Eldin Mohammed Fadul[1, *], Muneer Elyas Siddig Eltahir[2], Idris Musa Adam[3], Abbas Hassan Ali[3], Hatim Abdalla Elkhidir[3], Mustaffa Abdalla Nasreldin[4], Sona Mohammed Fadual[5], Mohammed Mukhtar Ballal[4]

[1]Department of Forest Silviculture, Faculty of Forestry, University of Khartoum, Khartoum, Sudan

[2]Institute of Gum Arabic Research and Desertification Studies, University of Kordofan, Khartoum, Sudan

[3]Gum Arabic Research Programme, Agricultural Research Corporation, El-Obeid Research Station, El-Obeid, Sudan

[4]Gum Arabic Research Programme, Agricultural Research Corporation, Forestry and Gum Arabic Research Center, Soba, Sudan

[5]Department of Forest Protection and Conservation, Faculty of Forestry, University of Khartoum, Khartoum, Sudan

Abstract

This paper is an attempt to review some of the research work that was carried out by the Gum Arabic Research Division (GRD) during the period 2000 to 2025. The objectives is to give a highlight about the research finding that provided by the Gum Arabic Research Division and to disseminate these finding to the gum producers, stakeholders such as companies, forest administrations, producers association and the other relevant research institutes. During the period 2000-2025 many research excrement's were carried out by the gum arabic research scientist at El-Obeid, Kadugli and Nyala Research Stations. These experiments include tapping tools, date of tapping, tapping intensity, position of tapping (branch, lower stem, middle stem, and higher stem), tapping direction, the relationship between climatic factors, tapping and gum arabic yield, provenances trails and agroforestry trails. For tapping tools, the Sonki (new innovative tool developed by GRD) is found as a best tool for tapping *Acacia senegal* trees. It is reported that it has muti-function where it could be used for tapping the tree and harvesting the gum. The GRD was found that gum arabic yield was greatly influenced by tapping date, the gum yield (g/tree and g/picking) was higher when the trees were tapped on the 15th of October and 1st of November compared with other date of tapping. The GRD found that gum arabic yield prediction shortly before or after tapping is a achievable either by knowing the commencement of tapping or by knowing yield of the first picking. For the effect of tapping in various azimuth angles on gum arabic yield we found that gum yield of *Acacia senegal* increase by 67.6 and up to two folds as due to tapping in the Eastern and Western Sides of the branches towards direct sun light. 15 *Acacia senegal* provenances were examined in the nursery and under field conditions to identify which provenances that capable to grow and survive under a diverse environmental conditions at Eldamokey forest reserve. All *A. senegal* provenances gave a higher survival percentage of more than 90% under the dry climatic conditions at the experimental site. For agroforestry research it was found that intercropping of of *Acacia senegal* with groundnut, sesame and roselle provide a good household income from gum arabic production which can easily compensate for other crop yield losses. For tree spacing the finding from GRD indicated that crops yield and straw were affected by tree spacing thus recorded higher

*Corresponding author: kamaleldin2001@gmail.com (Kamal Eldin Mohammed Fadul)

Received: 9 June 2025; **Accepted:** 25 June 2025; **Published:** 19 July 2025

yield under wider spacing compared with the narrow ones. LER was higher under agroforestry system as compared to mono-cropping. The study concluded that gum arabic yield was greatly influenced by tapping date and tapping intensity. The gum yield of *Acacia senegal* increase due to tapping in the Eastern and Western Sides of the branches towards direct sun light. From and economical point of view, it is recommended that roselle and sesame can be intercropped with *A. senegal*.

Keywords

Gum Arabic, Date of Tapping, Tapping Tools, Tapping Intensity, Provenances Trails, and Agroforestry Research

1. Introduction

Sudan is the world's largest producer of gum arabic, which is one of the four important agricultural export commodities from Sudan, along with livestock, cotton and sesame. Over the last 20 years, gum arabic export value amounted on average to US$ 40 million annually. While there has been government intervention in the marketing of all agricultural exports in the past, gum arabic is the only one for which government controls remain. Historically, Sudan was known to be a major gum exporter, producing more than 80 percent of the supply in the world market [9, 18, 19].

Gum arabic is mostly produced by small-scale farmers in traditional rain-fed farming areas (central and western Sudan); they represent up to 20 percent of Sudan's population, or around 6 million people, and are among the poorest and most vulnerable to food insecurity [6].

Small-scale farmers who give priority to food crop production (usually sorghum or millet) to secure family nutritional needs but seek other sources of income to meet the household's basic needs other than grains. In addition to the direct financial returns, they cultivate gum arabic because this activity constitutes a crop diversification strategy to mitigate crop failure, has substantial beneficial environmental impact, and is an important source of on-farm supply of fuel wood and livestock fodder.

Acacia senegal (L.) Willd is a widespread species. It occurs naturally in a belt 300 km wide extending through the southern frontier of the Sahara Desert, from Mauritania to Sudan, Ethiopia, Somalia; also in east Africa and extend southward to Mozambique, Transvaal, Natal; along the southern coast of Africa and Iran; and in Pakistan and western India [10, 21].

In Sudan, *Acacia senegal* is found naturally in a belt commonly known as gum belt (Latitude 10 ° and 14 °N) Figure 1. This broad ecological region represents a complex and diverse environment with regard to climate, soils, vegetation, animals and human activities [5, 6]. These factors were reported by [27] to have an impact on gum yield. The species occurs under annual rainfall of 280- 450mm in sandy soils, in Kordofan, Darfur and western White Nile. Also, under an average rainfall of 500mm in the central clay plains [3, 5, 16], but can even grow under 200mm of rain, with 8-11 arid months, to 800mm [26].

In this paper we are trying to give a highlight about the research that was carried out by the gum arabic research division during the period (2000-2025) and to disseminate the research finding to the gum producers, stakeholders such as companies, forest administrations, producers association and the other relevant research institutes.

2. Gum Arabic Research Division (GAD)

The gum arabic Research division was established in 1958 mainly to carry out research on gum. However, in the absence of a production division, it also had to carry out extension work to increase gum arabic production [11]. Generally, the gum Arabic research division has experienced administration changes, in 1975 it was put under the umbrella of the Agricultural Research Corporation (ARC) so that it could benefit from the multi-disciplinary interaction and focus only on research and extension. In 1982 it was absorbed in the western Sudan Agricultural Research Project (WSARP) which is a part from the ARC. Nowadays, the division was worked in four Research Stations in El-Obeid, Nyala, El Damazin Research Stations, and Soba Forestry Research Center. The responsibilities of the gum Arabic research division (GRD) include

1) Conducting gum and resin research
2) Formulating of development plans for gum arabic to ensure continuity and sustainability of yield
3) Improvement of the silvicultural and management practices of the gum arabic and other gum producing trees
4) Providing and dissemination of the technical information to small gum producers within the gum arabic belt.
5) Conservation of the promising *A. seneal* seed provenances
6) Improvement of agroforestry systems adaptable to the gum belt environment
7) Improvement of the local knowledge of small gum producers by supporting them by the new technologies that lead to sustainable management of gum resources

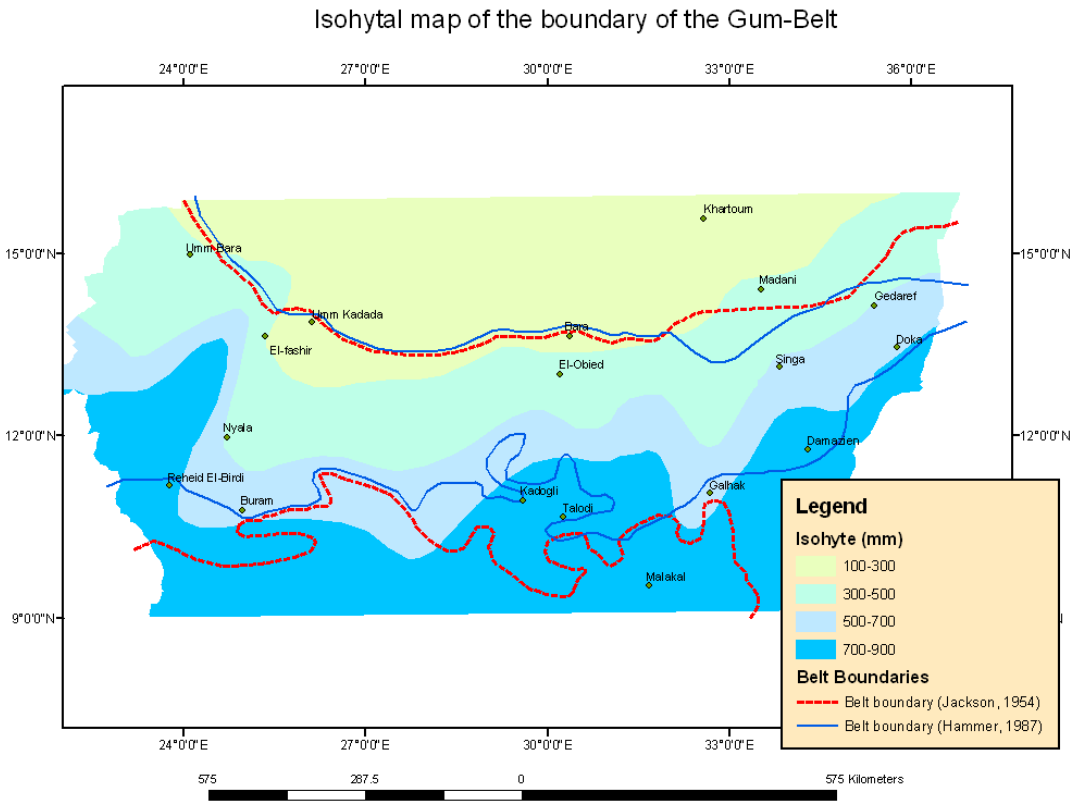

Figure 1. *Isohytal map of the boundary of the gum belt.*

3. Previous Research Work

3.1. Artificial Regeneration Trials

Some research work were done by the scientist in the gum arabic research division (GRD) covering seed germination, stumped transplant, seedling in soil blocks, sowing and planting in forest, sowing of seeds at grassland, sowing the seeds within the cultivation land, sowing in mechanized crop production schemes in Gedaref, in natural forests in Darfur, in agriculture experimental plots in El-Obeid town [23].

3.2. Gum Tapping and Tapping Tools

Gum tapping is the traditional way of producing gum in Sudan. Usually the tapping is done for *A. senegal* (gum arabic tree) by using small Axe (Farrar) or by using the developed new hand tool called Sonki [11]. The Sonki is driven under the bark of the tree without penetrating the wood between the outer bark and inner cambium [17]. A strip of bark (30 to 40cm) is then removed causing wounds which stimulate gum exudation [7].

The wound resulting from removal of the bark of the tree exposes the inner bark and the cambium of the tree to the external environment (light and wind) and hence the gum exudes cover the wound and thus the gum arabic is formed [2].

The gum arabic Research Program at El-Obeid Research Station developed an alternative tapping tool. The tool is composed mainly of an iron part of about 20cm long with a sharp pointed apex (3cm long) with a tool handle of 2.5m (Figure 2). This tool is known as Sonki which was proved to be less damaging to the tree compared with the traditional axe. According to [20] 95% of the Sonki users stated that "it is a good tool, save time, efficient, relevant to the tapping practice and functional". It was stated also the Sonki can be used for both tapping and collection. Moreover, women and teenagers could also use it. Sonki never recorded any damage to the trees compared with axe. Some producers mentioned that using Sonki increased the gum production. This tool is characterized by light weight, cheap in price and easy to access high branch.

Tapping was carried out at two intervals, the first tapping immediately after the rainy season (November) and the second tapping in summer (February) [26]. Tapping is usually done after the rainy season starting in October to mid of November.

3.3. Other Experiments

Other experiment has been carried out. The objectives were to enable more systematic comparison between different treatments, and to confirm or check the research finding obtained from the previous work [11]. These may be summarized as; germination of seeds and establishment of seedlings; effect of mulching on seed germination; shade tolerance of *A.*

*senega*l compared with other three species among its natural association; the effect of rainfall and soil type on regeneration of *Acacia senegal*; regeneration of *Acacia senegal* by Tuangya, Comparative methods of establishment of Hashab plantation, trails on chemical weed control, provenance trails, the effect of fire and locust damage on gum production and other research activities [23].

Most of the results of the experimental work of the GRD prior to its amalgamation with WSARP were documented. More recent reports written by the staff members of the GRD cover almost all aspects of gum arabic and are to be found in the archives of the Forest National Corporation (FNC), Khartoum, the Agricultural Research Corporation (ARC), Wad Medani, the Forestry Research Center, Soba, and gum Arabic Research Division at El-Obeid Research Station.

4. Recent Research Finding

4.1. Tapping Age and Tapping Intensity

Tapping of the gum tree generally starts when the trees are 3-7 years old with a height of about 1.2-3.7 m and diameter of 5cm [6]. However, the trees from coppice are tapped at the age of 3-4 years age, while trees from seedling are tapped at the age of 5 year. In addition, the trees grown naturally are tapped at the age of 6-7 years old. Gum yield varies considerably with variation in the genetically make up of the tree, its environment and management practices such as tapping methods and intensity of tapping.

The same author cited variable gum yield figures ranging from 0.1-2kg/ tree/ year as reported by different authors [6, 21]. The GRD investigated the effect of time and intensity of tapping (the number of branches tapped per tree), showed that earlier tapping as in mind October significantly increases gum yield. The mean yield was only 7.1-8.8kg/tree/ year in late tapping e.g. 30th November and 15th December, respectively [8]. The same author recommended that tapping the minimum number of branches per tree is necessary for sustaining yield without weakening the tree.

4.2. Determination of Optimum Date of Tapping

The time for tapping the tree is differs with local climatic conditions [6]. Rainfall and temperature variations were found to affect the time of tapping and consequently gum yield [4].

Tapping is carried out after the rains or when the growth stops and the leaves become yellowish in colour and began to shed [8]. Late tapping after the cold spell is over, is done when the rainy season is too long resulting in continued growth. Tree defoliated by locust or browsed by camels are also delayed for tapping because they continue to grow instead of entering into a dormancy period, which precede gum exudation [8].

The time of tapping is very critical and unless it is done timely. The farmers may lose the whole or part of his gum yield if he taps the tree lately. However the procedures followed in tapping is similar for both plantation and natural stands. Traditionally, the gum producers tend to tap late after harvest of their agricultural crops [13].

GRD at El-Obeid and Kadugli Research Stations carried out several experiments for t determination of the optimum date of tapping**,** Adam and Fadl 2008/09 and 2009/010 studied the effect of tapping date for gum arabic production in South Kordofan State. They studied six tapping date (1 Oct, 15th Oct, 1 Nov, 15th Nov, 1 Dec and 15th Dec) a simple financial analysis of gross surpluses was used to evaluate the productivity and profitability of the different treatments.

The results of 2008/2009 season yields differed significantly by date of tapping (p<0.001) for all picking except the fifth picking (Table 1). Tapping on 15 October and 1 November yielded 1038.5 g and 482.3 g, respectively, both significantly higher than on the other tapping dates. The total gum yield (g/tree) in this season showed highly significant differences ($p < 0.001$) between the tapping dates. The highest total gum yield of 1038.5 g/tree was recorded when the trees were tapped on the 15th of October while the lowest total gum yield of 285.3 g/tree was recorded when the trees were tapped on the 1st of October. The effects of tapping date on *A. senegal* gum yield in the second season 2009 are shown in Table 2. Analysis of variance indicated significant differences ($p <$ 0.001) between the dates of tapping on gum arabic yield. Tapping of *A. senegal* trees on the 15th of October and 1st of November gave a yield of 450.8g/picking and 274.6g/picking, respectively, which are significantly higher that on other dates of tapping. The total gum yield in the second season was significantly ($p < 0.001$) affected by the date of tapping. The highest total gum yield of 1164.8 g/tree was recorded when the trees were tapped on 15 October followed by 840.1 g/tree on 15 November, while the lowest total gum yield of 324.4 g/tree was recorded when the trees were tapped on 1 October Figure 5.

The combined analysis over season for the gum yield (g/picking) and for the total (g/tree) showed significant effects ($p\leq 0.01$) of tapping dates on gum yield. The higher total gum yield of 1360 (g/tree) was recorded when the *A. senegal* trees were tapped on 15 October followed by 661.2 (g/tree) on 1 November and the lowest gum yield of (386.1 g/tree) was recorded when the trees were tapped on 15 November. The gum arabic yield is highly governed by the end of the rainy season more that any specific calendar date. The difference in gum yield was attributed to high rainfall in two seasons which ranged between 350–750mm. Soils of the South Kordofan are almost clay soil (> 90% clay). This result can be used by farmers to gain more yield and to obtain 7−8 gum pickings rather than rely on 4- 5 pickings. In conclusion, *A. senegal* gum arabic yield was greatly influenced by tapping date, the gum yield (g/tree and g/picking) was significantly higher when the trees were tapped on the 15th of October and 1st of November compared with other date of tapping. These finding

can be used to increase gum arbaic production in South Kordofan State and increase the household income especially during the dry season, this can compensate for crop failure.

In North Kordofan**,** The GRD studied the effect of date of tapping and stand type on gum yield. The highest yield obtained for all type of stands was found on early of (1 October to 1 November) tapping.

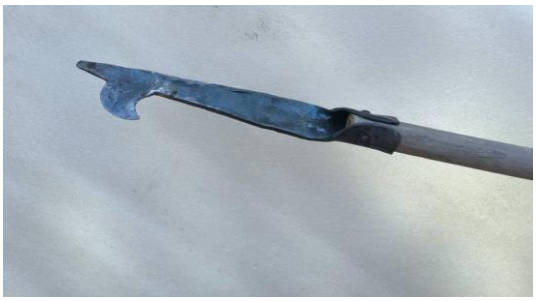

Figure 2. *The Sonki innovated tapping tool which was developed by GRD, for tapping Acacia senegal.(Photo authorized Munner).*

Table 1. *Gum arabic Yield (g/picking) in South Kordofan State in Relation to Date of Tapping Season 2008/2009.*

Date of Tapping	Gum Yield (g/picking)								Total gum (g/tree)
	1	2	3	4	5	6	7	8	
1st Oct	4.7	0.0	92.3	82.8	44.4	32.1	20.3	8.7	285.3
15th Oct	9.5	42.3	375.2	252.7	143.6	96.9	94.6	23.7	1038.5
1st Nov	48.6	45.6	155.8	107.2	56.9	40.6	18.5	9.1	482.3
15th Nov	52.2	55.9	84.3	94.2	63.5	44.2	25.0	1.7	421
1st Dec	45.3	66.4	127.0	116.9	59.8	36.9	0.7	6.7	459.7
15th Dec	43.1	127.0	83.4	78.4	62.0	0.0	1.3	0.0	395.2
Means	33.9	56.2	153	122.0	71.7	102.7	26.7	8.3	492.8
SE±	11.7*	8.8**	26.0**	18.3**	16.8*	7.9**	5.0**	2.4**	47.2**

Adam and Fadl, 2011, Journal of Forestry Research

Table 2. *Gum arabic Yield (g/picking) in South Kordofan in Relation to Date of Tapping Season 2009/20010.*

Date of Tapping	Gum Yield (g/picking)								Total gum (g/tree)
	1	2	3	4	5	6	7	8	
1st Oct	4.2	0.0	93.8	75.4	54.4	46.2	25.2	25.2	324.4
15th Oct	7.5	60.5	450.8	325.5	159.7	78.5	58.2	24.11	1164.8
1st Nov	34.2	93.0	274.6	161.1	120.0	84.4	54.1	18.7	840.1
15th Nov	24.2	80.6	235.0	166.1	101.7	72.0	33.2	1.3	714.1
1st Dec	29.0	80.4	218.4	192.7	77.3	52.0	0.0	1.0	650.8
15th Dec	37.0	60.3	197.8	122.3	48.1	0.0	0.0	0.7	466.2
Means	22.7	62.5	245.1	173.8	93.5	55.5	28.4	11.8	766.9
SE±	5.2 **	16.6*	48.8**	32.9**	25.6ns	11.8**	8.1**	3.0**	101.8**

Adam and Fadl, 2011, Journal of Forestry Research

4.3. Effect of Tapping in Various Azimuth Angles on Gum Arabic Yield in North Kordofan State

Gum yield varies greatly with differences in husbandry practices namely the time and intensity of tapping, and tapping methods [7]. The objective of this research work was to determine whether the gum arabic yield is affected by the method of tapping – specifically the site of the tapping in relation to the direction of sun light, and to recommend management guidelines to improve gum arabic production;

The GRD carried out an experiment at El Damokeya Forest Reserve for the seasons (2006/2007 and 2007/2008) to determine the effect of tapping in various azimuth angles on gum arabic yield in North Kordofan State. The results showed that there is a significant difference on all gum pickings and the percentages of the yielding trees in relation to tapping sides (Tables 3 and 4). Similarly, the gum yield and the number of yielding trees increased in the Eastern and Western sides tapping as compared with that of Northern and southern sides. The division found that the gum yield of *Acacia senegal* increase by 67.6 and up to two folds as due to tapping in the Eastern and Western Sides of the branches towards direct sun light. Similarly, the number of yielded trees was higher for those tapped in the East and West sides compared to trees tapped in the Northern and Southern sides [1].

Table 3. *Effect of tapping side on gum arabic yield (g/pick) in North Kordofan State (Season 2006/2007).*

Tapping side	Pickings			Mean yield (g/pick)
	1	2	3	
North	27.4	22.6	40.0	36.9
South	31.2	27.7	41.8	41.3
East	61.6	63.6	49.4	64.4
West	51.8	65.5	48.6	65.0
Mean	43.5	44.9	45.0	53.6
SE ±	3.27**	5.16**	2.67ns	2.79**

** Significantly at $P \leq 0.01$, * Significantly at $P \leq 0.05$ and ns not significant
Source: Proceeding of the 45th meeting of the National Crop Husbandry committee

Table 4. *Effect of tapping side on gum arabic yield (g/pick) in North Kordofan State (Season 2007/2008).*

Tapping side	Pickings					Mean yield (g/pick)
	1	2	3	4	5	
North	22.2	27.40	18.07	34.31	1.5	20.70
South	25.84	32.91	35.35	25.44	0.77	24.06
East	49.13	89.20	74.61	80.21	72.82	73.19
West	46.34	66.22	87.99	56.2	45.68	60.49
Mean	35.88	53.93	54.01	49.04	30.19	44.61
SE ±	7.26 ns	12.3*	10.84**	11.35*	12.74	7.02**

** Significantly at $P \leq 0.01$, * Significantly at $P \leq 0.05$ and ns not significant
Source: Proceeding of the 45th meeting of the National Crop Husbandry committee

Figure 3. *Farmers training in gum tapping and Tapping tools, North Darfur (Photo authorized Kamal).*

4.4. Effect of Date of Tapping and Tapping Tools on *A. Seyal Var Seyal* Gum Yield

Acacia seyal var. *seyal*, locally known as talh, belongs to the family Mimosaceae. Under favorable conditions, the small to medium sized tree reaches a height of 17m, has a stem diameter of 60cm, and develops a characteristic umbrella-shaped crown. The bright green bark is covered with either a pale grey- green or rust-red powdery coat. The dark green leaves have 4 to 12 pairs of pinnae and 10 to 22 pairs of leaflets. Flowers have shiny yellow globose heads. Two or three are together at the leaf axils. Pods are slightly curved, light brown at maturation, and 10 to 15cm, long. The slash is bright red, mottled and exudes a yellowish gum [15]. No information is available about the tapping possibilities of *A. seyal var. seyal* for gum production.

Therefore, two experiments were conducted by GRD at Umfakarin forest reserve (South Kordofan) to investigate the effect of different tapping tools (makmak, axe, mofar and sonki) and tapping positions (low stem, middle stem, high stem and branches) on talh gum yield of *A. seyal var. seyal*. Trees were tapped on the 1st of November, and gum was collected four times (1st Dec., 1st Jan., 1st Feb. and 1st March) Figure 4. The results of the first experiment clearly indicate that the makmak is best tools for tapping *Acacia seyal var seyal*. In the second experiment, the middle stem tapping caused the highest gum yield with a total yield of 275 g/tree. The results indicate that tapping of *A. seyal var. seyal* is a promising technique for talh gum production Tables 5 & 6. The removal of bark to expose the wood surface stimulated gum excretion on *A. seyal var. seyal* in both experiments. The results of the first experiment clearly show that the tapping tool had a great influence on the amount of talh gum production of *A. seyal var. seyal* (Table 5). Over the season the trees produced the most gum when they were tapped with the makmak and the lowest when tapped with the sonki. In comparison to trees tapped with makmak, trees tapped with axe, mohfar or sonki produced 58, 59, and 75% less gum, respectively. The reasons can be seen in the wide edge on the top of the tool, which allows one to remove a big piece of the bark. The lowest gum yield was obtained from trees which were tapped with the sonki. The sonki was originally developed by the Agricultural Research Corporation in Sudan for tapping *A. senegal*. Today it is commonly used by tappers in Kordofan for hashab gum production. However, due to the different bark of *A. seyal var. seyal* compared to *A. senegal*, the sonki is not suitable for tapping *A. seyal var. seyal* [14].

Table 5. *Average yield of talh gum (g/ picking and g/tree) as affected by tapping tool at Um Fakarin forest reserve.*

Tapping tools	Pickings				Total yield (g/tree)
	1	2	3	4	
Makmak	144.84a	30.7ab	132.02a	20.88c	328.6
Axe	55.64b	40.66a	35.68b	45.68ab	177.2
Mohfar	44.42b	40.78a	25.77b	58.64a	169.6
Sonki	29.83c	23.61bc	21.37b	30.16c	105.0
Position of tapping					
Low stem	66.86a	52.18a	28.60ab	56.36ab	204.00
Middle stem	84.55b	98.42b	31.78a	60.76a	275.51
High stem	31.08c	35.36a	18.96c	32.45c	117.85
Branches	66.78a	37.08a	22.14b	36.04b	162.04

Table 6. The interactions of tapping intensity and tapping date on talh gum yield at Um Fakarin Forest Reserve.

Tapping date	Gum yield (g/tree) Tapping intensity				Mean
	2	4	6	8	
1 November	203.38a	178.56a	183.99a	176.95a	185.72
15 November	144.56b	156.80b	177.80a	175.66a	163.71
1 December	120.28c	118.64c	89.47b	100.65b	107.26
Mean	156.07	151.33	150.42	151.09	152.23

* Means followed by the same letters on the same column are not significantly different at 5% level of probability.

Figure 4. Gum exudation from Acacia seyal var seyal tree (Photo authorized Kamal).

Figure 5. Gum yield from trees tapped by Sonki (Photo authorized by Kamal).

4.5. Gum Arabic Yield in Relation to Stand Type and Management in Western Sudan

The gum arabic yield varies as a result of complex factors of the physical, biological and socio-economic environment. The impact of these factors or some of them on gum arabic production has been reported by [3, 4, 24, 27]. Despite these attempts, yet there is information gap regarding the factors controlling gum arabic yield of the *A. senegal* tree. Presently the major problem facing the gum arabic industry in Sudan is a lack of reliable information on gum arabic yield and yield trends that can be used as a basis for monitoring gum arabic production [8].

The gum arabic research programme carried out a comparative study of gum arabic yield trends per tree and pickings in relation to stand management (by farmers and by researchers) and type (natural and planted) in two locations in North Kordofan State for three consecutive seasons. In addition 8 years yield trend in relation to rainfall were compared based on the 1993-2000 gum yield data from 1400 trees. Although the gum yield followed the same trend over time in all stands at both locations, the gum yield from farm stand whether planted or natural was 47% to 60% lower than that from research stands. Late tapping reduced the gum yield by 40% and 50% at the two different locations, respectively Table 7. Yield was highly affected by rainfall, correlating positively with rainfall in six of the eight years of the study. These findings can be used for improving gum arabic yield through management interactions and for predicting yield in relation to stand type, management regime and rainfall.

Table 7. The interaction of tapping intensity and tapping date on gum yield (g/tree) at El Himaira natural stands.

Tapping date	Tapping intensity								Mean
	1	2	3	4	5	6	7	8	
1 Oct	27.0a	25.5a	31.4a	33.1a	23.3a	31.0a	33.6a	31.1a	29.2
15 Oct	48.3abc	36.5bc	54.9ab	46.6abc	53.0ab	29.7c	64.2a	38.6bc	46.5
1 Nov	34.3c	43.9abc	38.0c	58.4ab	41.9bc	60.9a	36.0c	34.8c	43.6
15 Nov	21.2a	28.8a	27.6a	31.1a	35.7a	35.9a	26.6a	35.6a	30.3
1 Dec	26.0a	22.5a	28.4a	26.6a	35.7a	32.7a	23.5a	16.6a	26.5
15 Dec	12.5a	18.9a	20.7a	21.9a	21.7a	26.8a	18.6a	32.5a	21.7
Mean	26.3	29.0	33.5	36.3	35.2	36.2	33.7	31.5	

* Means followed by the same letters on the same column are not significantly different at 5% level of probability according to DMRT.

4.6. Research on Ecology of *Acacia Senegal*

A. senegal tree is the main species with vast geographical extent in the gum belt, which is about 300 km wide extending through the southern part of the Sahara Desert, from Mauritania to Sudan, Ethiopia, Somalia in east Africa, also in Iran, Pakistan and Western India [21, 25]. The herbaceous vegetation associated with the gum arabic tree varies considerably throughout the gum belt [17]. This association is belief in having a vital role in protection of the sandy soils beside a source of organic matter and nitrogen, which is necessary for sustained agricultural production. Therefore, proper and specific management of all ecological and environmental resources should be practiced to maximize the production and at the same time to minimize the losses of the trees. On the other hand, there is a strong held belief that presence of grasses under or around tree increases gum arabic yield. The more grasses exist, the more gum arabic yield expected. Based on these points of views, the GRD designed an experiment to investigate whether gum arabic yield from *Acacia senegal* is related, in a way or another, to the presence of grasses under the gum arabic tree.

The objective was to develop an understanding of the ecological effects of under-story vegetation and tapping date on the productivity of gum arabic from *Acacia senegal* as over story cover. The first factor was grass cover which was tested in four levels (100% and 50% grass cover in addition to bare and burnt). The second factor, date of tapping was tested in three levels namely (1st Oct, 15th Oct and 1st Nov). The first picking was done after 45 days from tapping and the gum yield up to seven pickings was collected at intervals of 15 days. The results showed that gum arabic yield was significantly increased by increase in density of grasses and the date of tapping was proved to have significant effect on gum yield Table 8. The early tapping gave more gum yield compared with the other dates of tapping. Furthermore, the density of grasses and the date of tapping have a significant effect on number of gum pickings.

Table 8. Gum arabic yield (g\picking) in relation to date of tapping and density of densities at El Demokeya Sites during 2004.

El Demokeya									
Grass density	Date of tapping	Picking number							Total
		1	2	3	4	5	6	7	
100	1st Oct	89.4a	18.0e	13.9cd	7.3e	2.9f	8.3d	0.0c	139.8
	15th Oct	55.7b	19.8e	4.6fg	3.9e	4.7f	10.9c	0.0c	99.6
	1st Nov	17.1e	2.7f	10.1de	14.3d	0.0f	0.0e	0.0c	44.2
50%	1st Oct	84.1a	53.1ab	52.1a	22.2c	25.3b	31.1a	25.7a	293.6
	15th Oct	37.0d	29.6d	14.7c	21.6c	14.7de	13.3b	0.0c	130.9

El Demokeya									
Grass density	Date of tapping	Picking number							Total
		1	2	3	4	5	6	7	
	1st Nov	21.2e	5.8f	14.6c	6.5e	41.3a	0.0e	0.0c	89.4
0% (bare)	1st Oct	56.8b	56.5a	28.9b	12.5d	4.7f	9.5cd	3.7b	172.6
	15th Oct	55.2b	49.2bc	9.9de	0.0f	11.7e	10.9c	2.7b	139.6
	1st Nov	47.3c	44.9c	1.4gh	26.6b	17.8cd	10.6c	4.4b	153.0
0% (burnt)	1st Oct	53.1b	1.3f	17.2c	0.0f	12.3de	11.5bc	0.0c	95.4
	15th Oct	0.0f	2.8f	6.6ef	4.1e	21.2bc	0.0e	0.0c	34.7
	1st Nov	3.9f	6.5f	0.0h	33.7a	0.0f	0.0e	0.0c	44.1
Means		42.9 ±1.9	24.2 ±2	14.5 ±1.4	12.7 ±1.1	13.1 ±1.9	8.8 ±0.77	3 ± 0.78	119.7

4.7. Agroforestry Research in GRD

Research on adoption of agroforestry innovations is critical because during the past decades it has become clear that there is a gap between advances in agroforestry science and the success of agroforestry-based development programs and projects [19]. It is fundamental to understand how and why farmers make long-term land-use decisions because this knowledge should be applied when developing, designing and "marketing" agroforestry innovations. Many research works were done by the gum arabic researchers in North Kordofan and South Darfur Sates. For example in North Kordofan Fadl and El sheikh 2004/05 and 2005/06 studied the effect of *Acacia senegal* agroforestry system on growth and yield of groundnut (*Arachis hypogea*), sesame (*Sesamun indicum*) and roselle (*Hibiscus sabdariffa*). The results indicated that intercropping reduced groundnut yield by 26%, sesame by 21% and roselle by 20%. Gum yield at Eldamokeya was significantly ($P \leq 0.05$) under groundnut, sesame and roselle intercropping system (Table 9). The yield per tree was computed per ha (375 trees per ha). In all pickings, the average yield ranged between 12 and 40 g/picking/tree. In the first season, the highest production per tree for the four pickings (124g) was obtained in pure stand of *A. senegal*, followed by intercropped roselle (108g) intercropped groundnut (97g) and intercropped sesame (89g). in the second season (2005), the higher yield (122g) was obtained in sole *A. senegal* followed by roselle intercropped (113g), groundnut intercropped (106g) and intercropped sesame (92g). The effect of cropping season on gum yield (g/tree) was not significantly different ($P \leq 0.05$). All the treatments gave LER of more than one—indicating the superiority of growing the field crops in intercropping over the sole cropping systems. The highest LER of (1.71) was obtained when roselle was intercropped with *A. senegal*, while the lowest LER (1.48) was obtained when groundnuts were intercropped with *A. senegal* (Table 10). All the treatments gave positive net revenues, the highest being for intercropped roselle (438 SDG/ha). The intercropping of sesame gave the second highest net revenue (387 SDG/ha), while the sole roselle gave the lowest net revenue (97 SDG/ha) (Table 11). They concluded that Agroforestry systems including *A. senegal* provide a good household income from gum Arabic production which can easily compensate for other crop yield losses [13]. Systems combining *A. senegal* and crops such as groundnuts, sesame and roselle have a useful role to play in sustaining agriculture and providing revenues in the arid areas of North Kordofan. From land use efficiency, productivity and profitability point of view.

The GRD 2010 and 2011 carried out an assessment to the agroforestry systems in North and South Kordofan States with objectives to identify and assess the most important agroforestry systems, to characterize major tree species in different agroforestry system, to prioritize major constraints on agroforestry systems in the region, and to study the current status of gum arabic trees and their contribution on farmers livelihood [24]. They concluded that in the traditional rainfed area of Kordofan region and with increasing rate of desertification and natural resources degradation managing the traditional field crops with *Acacia senegal* and other tree species can increase productivity and crop value, and improve land use efficiency. The agroforestry systems in this area have a useful role to play in sustaining agriculture production and providing revenues in the arid areas of Kordofan region. The most important agroforestry system in the study area was found to be *Acacia senegal* agroforestry system Figure 6. Shifting cultivation is still practice by more than 50% of the respondents. Trees have a positive effect in restoring soil fertility and improving the microclimate.

In South Darfur, the GRD studied the effect of *A. senegal*

re-spaced at 4 x 4, 4 x 8m, and 8 x 8m on yield of millet, sorghum and sesame intercropped with *A. senegal*, Moreover, to asses gum arabic yield and land Equivalent Ratio (LER). The results indicated that crops yield and straw were affected by tree spacing thus recorded higher yield under wider spacing compared with the narrow ones. LER was higher under this agroforestry system as compared to mono-cropping [22]. Gum arabic yield was higher in the 4 x 8m tree spacing than the other spacing Tables 9 and 10.

Table 9. *Gum yield (g/tree) under different cropping system at Eldamokeya forest reserve during growing season 2004 and 2005.*

Cropping systems	Pickings				Total
	1	2	3	4	
Season 2004					
Pure Acacia senegal	35.1a	40.1a	27.1a	21.7a	124
Roselle intercropping	29.6b	36.3ab	23.5b	18.5b	107.9
Groundnut intercropping	28.0b	32.6bc	20.5c	16.0bc	97.1
Sesame intercropping	29.10b	28.5c	17.5d	13.8c	88.9
SE ±	0.55**	1.18*	0.82**	0.87**	
Season 2005					
Pure Acacia senegal	36.8b	39.5a	26.4a	19.1a	121.8
Roselle intercropping	34.3a	36.0a	27.6a	15.6b	113.5
Groundnut intercropping	38.5a	35.0a	24.8ab	12.9c	106.2
Sesame intercropping	26.0b	29.9b	21.9b	13.9bc	91.7
SE ±	0.58**	1.2*	0.48**	0.70**	

Table 10. *Land equivalent Ratio (LER) for the tested crops in the intercropping with A. senegal and sole cropping system.*

Cropping systems	Crop yield (kg/ha)	Gum yield (kg/ha)	LER
Pure Acacia senegal	-	46	-
Sole groundnut	483.7	-	
Groundnut intercropped	356.3	34	1.48
Sole sesame	346.8	-	-
Sesame intercropped	302.6	38	1.62
Sole Roselle	177.8	-	-
Roselle intercropped	140.30	42	1.71

Table 11. *Partial budget for groundnut, sesame and roselle intercropped with Acacia senegal and ranked in order of increasing total production cost.*

Cropping systems	Yield (kg/ha) Gross revenue Production cost Net revenue			
	SDG/ha	SDG/ha	SDG/ha	SDG/ha
Pure A. senegal	37	266	35	231

Cropping systems	Yield (kg/ha)	Gross revenue	Production cost	Net revenue
	SDG/ha	SDG/ha	SDG/ha	SDG/ha
Sole groundnut	387	325	228	97
Groundnut intercropped	285	433	263	170
Sole sesame	278	399	184	295
Sesame intercropped	242	606	219	387
Sole Roselle	272	598	249	345
Roselle intercropped	217	722	284	438

Table 12. *The effect of tree spacing on crop yield (kg/ha).*

Tree spacing (m)			
	Millet		
	Season 2001	season 2002	season 2003
4x4	33.2a	13.67a	161.6b
4x8	42.0a	50.04b	553.6b
8x8	42.9a	101.0a	55582.0a
Control	37.0a	181.0a	1600.0b
LSD	26.76	27.48	2703
CV%	30.0	22.9	95.81
	Sorghum		
	Season 2001	season 2002	season 2003
4x4	30.35b	45.8b	-
4x8	292.45a	139.97	-
8x8	440.64a	112.3 ab	-
Control	394.0a	249.0a	-
LSD	202.1	83.89	-
CV%	35.05	37.25	-
	Sesame		
	Season 2001	season 2002	season 2003
4x4	8.75b	25.33a	161.0a
4x8	26.6 ab	48.99a	73.67a
8x8	43.41a	114.8a	181.7a
Control	66.0a	239.0a	214.0a
LSD	29.04	93.85	165.6
CV%	48.8	65.67	48.07

Means followed by the same letters are not significantly different at 5% level, - No available data (crop failure)
Source: Publication of the National Crop Husbandry Committee, Wad Medani, 2008

Table 13. Gum arabic yield (g/tree) under the sole trees and intercropping for the period 2001 to 2002.

Treatment (M)	Intercropped		Control		Intercropped		Control	
	Pick 1	Pick 2	Pick 1	Pick 2	Pick 1	Pick 2	Pick 1	Pick 2
4 x 4	7.5b	7.30 a	3.30 b	5.90 b	4.93 b	5.40 a	4.70 a	5.00 a
4 x 8	11.2 a	6.70 a	13.5 a	12.2 a	7.85 a	4.10 a	5.20 a	3.50 a
8 x 8	8.5 ab	8.15 a	6.20 b	5.60 b	6.0 ab	4.10 a	4.10 a	7.00 a
LSD	3.22	3.54	3.94	2.77	2.63	4.59	2.00	4.99
CV%	16.04	21.11	20.54	16.24	22.04	42.65	20.99	43.03

Means followed by the same letters are not significantly different at 5% level

Figure 6. Tree crop interaction in North Kordofan State (Photo authorized Kamal).

4.8. Provenances Trails

Despite the economical importance of the gum arabic trees, few attempts were made to select high gum yielder trees of *A. senegal*. In 1967 the GRD selected a seeds from the gum belt areas and planting their progenies in a progeny test in El-damokeya Forest Reserve in western Sudan. Since 1967 till now serious research was done for and continued to be done on the selection and planting of a high yielding *A. senegal* trees for the rehabilitation of the degraded land of the gum arabic belt of western Sudan. Therefore, the objectives of the provenance trails is to evaluate the growth performance of *A. senegal* provenances at the nursery stage and under field condition to identify the provenance that has the capability to grow and yield under harsh environment and soil conditions as prevailing in the experimental site.

Two experiments were carried out by the researchers in the GRD during the growing seasons 2010\2011 and 2011\2012 in the nursery and under field conditions at El-Obeid Research Station and Eldamokey Forest Reserve. The objectives of the experiments were to study the growth performance of 15.

Acacia senegal provenances in the nursery and under field conditions to identify which provenances that capable to grow and survive under a diverse environmental conditions at El-damokey forest reserve Tables 14 and 15. For the nursery experiment, the results showed significant differences ($P \leq 0.05$ and $P \leq 0.01$) for shoot length, root length, number of leaves and stem diameter after two, three and for month from planting (Figure 6). At Eldamokeya Forest Reserve the results showed significant differences ($P \leq 0.05$ and $P \leq 0.01$) for survival percentage in the two seasons and number of branches in the second season (Figure 7). The combine analysis showed significant differences for survival percentage and number of branches Table 16. Furthermore, all *A. senegal* provenances gave a higher survival percentage of more than 90% under the dry climatic conditions at the experimental site. The results suggested that the two provenances 2&9 are a suitable candidate for rehabilitation of Eldamokeya forest reserve and the degraded area of the gum arabic belt of western Sudan [12]. Most of these provenances started to yield gum Arabic but now and due to the war this experimental site is not accessible.

Table 14. Acacia senegal seed provenances tested at El-Obeid Research Station nursery and in Eldamokeya Forestry Reserve, North Kordofan State, Sudan.

Provenances Code	Provenances name	Latitudes (N)	Longitudes (E)	Altitude (m)	Soil Type
1	El Damokeya	13 16	30 29	560	Sand

Provenances Code	Provenances name	Latitudes (N)	Longitudes (E)	Altitude (m)	Soil Type
2	Um Rwaba	12 52.237	31 02. 098	1565	Sand
3	El Rahad	12 46. 772	30 37. 280	1663	Sand
4	Abassyia	11 °40	31 °00	1240	Clay
5	Ambair	11 51.657	30 46. 244	1985	Clay
6	Umbrambeata	11 51.431	30 38. 77	1917	Clay
7	Habila	11 56. 412	30 01. 89	2176	Clay
8	Wasata	12 °49.29	29 °16.377	2021	Sand
9	Nabag	12 33.956	29 56. 35	1906	Sand
10	Saata	12 °46.89	29 °23.89	2009	Sand
11	Um Kreidem	13 °38. 808	29 °35. 015	2093	Sand
12	El Mazroub	13 °46.76	29 °13. 814	1972	Sand
13	Eyal Bakheet	13 °21. 886	28 °41.08	1929	Sand
14	Elnuhud	12 °39.69	28 °22.44	1831	Sand
15	El Khwai	13 °01. 343	29 °13.43	2026	Sand

Figure 7. *Acacia senegal seedling at the nursery stage (Photo authorized Kamal).*

Figure 8. *Acacia senegal seedling after six months from field planting at Eldamokey Forest reserve (Photo authorized Kamal).*

Table 15. Seed Characteristic of Acacia senegal provenances during 2010.

Provenances Code	Seed Purity%	Number of Seed\kg	Seed Moisture%	Germination%	Seed viability%
1	96.7	14665	3	66.0	94
2	97.3	15360	3	68.5	98
3	96.3	12370	5	71.0	98
4	96.7	13360	7	71.0	98
5	98.5	13640	3	79.5	92
6	98.5	13980	3	59.0	96
7	96.2	12970	3	74.0	100
8	98.7	11640	4	63.0	96
9	92.1	16750	3	44.5	96
10	97	14320	9	63.5	84
11	96.4	13350	6	74.5	98
12	98.2	13120	7	74.0	100
13	98.9	13560	5	67.0	82
14	97.7	10120	9	70.5	100
15	97.7	12340	4	65.5	96
Means	97.3	1256	4.9	67.4	94.8

Table 16. Combine analysis over season for Survival percentage, seedling height, diameter and number of branches.

Provenances Code	Survival%	Height (cm)	Diameter (mm)	No. Branches
1	95.1	34.3	0.6	4.4
2	99.2	36.8	0.5	5.2
3	97.0	31.7	0.6	5.5
4	98.2	37.9	0.6	8.6
5	98.7	35.5	0.5	5.4
6	98.7	32.2	1.2	5.1
7	97.1	32.9	0.5	4.4
8	98.2	32.5	0.6	6.0
9	99.5	32.4	0.6	7.2
10	95.4	33.0	0.7	8.4
11	95.7	35.5	0.6	10.7
12	94.3	39.3	0.6	6.8
13	95.3	33.7	0.7	7.2
14	96.7	34.9	0.6	3.5
15	95.7	34.9	0.5	5.2
Means	96.7	34.3	0.6	6.2
SE	0.81**	1.87ns	0.18ns	1.0**

Provenances Code	Survival%	Height (cm)	Diameter (mm)	No. Branches
CV%	20.3	15.4	43.8	45.7

5. Conclusion and Recommendation

Gum arabic yield was greatly influenced by tapping date, the gum yield (g/tree and g/picking) was significantly higher when the trees were tapped on the 1st of October and 15th of November compared with other date of tapping.

Tapping date, intensity of tapping, rainfall and maximum temperature at gum collection are the most important variable influencing gum arabic yield from *Acacia senegal* tree. Based on these finding it seems that gum arabic yield/production in western Sudan is less risky than agricultural crops, which face more frequent failure. However, gum Arabic yield prediction shortly before or after tapping is achievable either by knowing the commencement of tapping or by knowing yield of the first picking.

The gum yield of *Acacia senegal* increase due to tapping in the Eastern and Western Sides of the branches towards direct sun light. Similarly, the number of yielded trees was higher for those tapped in the East and West sides compared to trees tapped in the Northern and Southern sides.

Gum arabic yield was significantly increased by increase in density of grasses and the date of tapping was proved to have significant effect on gum yield. The early tapping gave more gum yield compared with the other dates of tapping. Furthermore, the density of grasses and the date of tapping have a significant effect on number of gum pickings.

Agroforestry systems including *A. senegal* provide a good household income from gum Arabic production which can easily compensate for other crop yield losses. Systems combining *A. senegal* and crops such as groundnuts, sesame and roselle have a useful role to play in sustaining agriculture and providing revenues in the arid areas of North Kordofan. From land use efficiency, productivity and profitability point of view.

Based on the above mentioned finding the following recommendation can be made:

1) The optimum tapping date of plantation and managed natural stands of *Acacia senegal* is 1 October to 15 October.
2) Gum gardens and natural farm stands of *Acacia senegal* should be tapped in 1 October to 1 November.
3) Gum arabic yield of a coming season is predictable using a prescribed plan of tapping in term of time and intensity and using temperature forecasts.
4) The early tapping gave more gum yield compared with the other dates of tapping. Furthermore, the density of grasses and the date of tapping have a significant effect on number of gum pickings.
5) To increase gum arabic production in South Kordofan it is recommended to tap the tree during the period from 15 October to 1 November.
6) From and economical point of view, it is recommended that roselle and sesame can be intercropped with *A. senegal*.

Abbreviations

GRD	Gum Arabic Research Division
LER	Land Equivalent Ratio
FNC	Forest National Corporation
ARC	Agricultural Research Corporation
WARAP	Western Sudan Agricultural Research Project

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Adam I M, Fadl K E M (2008**)** Effect of tapping in various azimuth angles on gum arabic production in North Kordofan State, Sudan, Proceedings of the 44th meetings of the Nation Crop Husbandry Committee, Wad Medani, 2008.

[2] Adam I M, Fadl K E M (2011) Effect of Grass Densities and Date of Tapping on *Acacia senegal* Gum Yield in North Kordofan State, Sudan. *Journal of Forestry Research (2011) 22(4).*

[3] Ahmed, E. A. (1986). Some aspects of dry land afforestation in the Sudan with special reference to *Acacia tortilis* (Forks) Hayne, *A. senegal* Willd. And *Prosopis chilensis* (Molina) stuntz. Forest Ecology and Management, 16: 209-221.

[4] Awouda, E. H. M. (2000). Production and commercialization of gum Arabic. Workshop on management of Trees for Farmland Rehabilitation and Development, Khartoum, Sudan.

[5] Badi KHM, Ahmed AE, Bayoumi MS. 1989. The forest of the Sudan. Khartoum, Sudan: Agricultural Research Council.

[6] Ballal, M. E. (1991). *Acacia senegal*: amulti-pupose tree species for the arid and semi- arid tropics. M. Sc. theses University of Wales, UK.

[7] Ballal ME. 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.

[8] Ballal, M. E. (2008). Relation between environmental factors, tapping date, tapping intensity and gum arabic yield of *Acacia senegal* plantation in western Sudan. Proceedings the 44th meetings of the Nation Crop Husbandry Committee, Wad Medani, 2008.

[9] Beshai, A. (1984). "The economics of a primary commodity: Gum Arabic", Oxford Bulletin of Economics and Statistics, 46(4): 371-381.

[10] Brenan, J. P. M. (1983). Manual on Taxonomy of *Acacia* species, FAO.

[11] El Khalifa MD, El Samani MO, Abdel Nour HO, Pearee DW, Barbier FB, Markang A, Burgess JC, 1989. Gum Arabic Belt Rehabilitation in the Republic of the Sudan. Stage I Report Volume 3: Endsleigh Street. London WC, HODD. England. Institute of Environmental Studies. University of Khartoum, Sudan.

[12] Fadl K E M, Ali A H, ELkhidir H *(2014***)** Evaluation of fifteen *Acacia senegal* Provenances in the Nursery and under Filed condition in North Kordofan State, Sudan. *Sudan Journal of Desertification Research (2014). Vol. 6(2): ISSN: 1858-5515.*

[13] Fadl K E M, El sheikh S A (2009) Effect of *Acacia senegal* on growth and yield of groundnut, sesame and roselle in an Agroforestry system in North Kordofan State, Sudan. *Journal of Agro for Syst*. Vol 78, No 3, pp 243- 252, https://doi.org/10.1007/s10457-009-9243-9.8 July 2009.

[14] Fadl K E M**,** Gebauer, J (2004**)** Effect of different tools and different tapping positions on (talh gum) yield of *Acacia seyal var seyal* in South Kordofan, Sudan. Afull paper online publication of the conference on International Agricultural Research development, 1-6, http://www.*Tropentag.de*

[15] Hall, V. M. P. (1961). Reports on Gum arabic 1958-161. Forestry Department, Khartoum, Sudan.

[16] Hussein SEG, Sulieman HM. 1999. Effect of regeneration methods and weeding treatments on establishment of *Acacia senegal* (L.) Willd. on clay soils. Journal of Agricultural Sciences, 7(2): 61−69.

[17] IIED and IES. (1989). Gum Arabic Rehabilitation in the Republic of the Sudan. Ministry of Finance and Economic Planning. International Institute of Environment and Development (IIED) and Institute of Environmental Studies (IES).

[18] Larson B. A. and Bromley D. W. 1991. "Natural resource prices, export policies and deforestation: the case of Sudan". World-Development, 19(10): 1289-1297.

[19] Macrae, J. and Merlin, G. 2002. "The prospects and constraints of development of gum arabic in SubSaharan Africa". Washington, D. C., World Bank.

[20] Muneer Elyas Siddig Eltahir, Kamal Eldin Mohamed Fadl, Mohammed Adam Abbas Hamad, Ahmed Ismail Ahmed Safi, Hatim Mohamed, Ahmed Elamin, Yahia Ibrahim Mohammed Abutaba, Faisal Ismail Musa, Tarig Elsheikh Mahmoud, Asmamaw Alemeu, Hamdon AliAbdelrhman, Osman Elsaid Adlan, Salih Omer Tutu, Mohammed Hamed Mohammed, Yahia Omer Adam Gumaa, Awadelkareem SulimanOsman Khalifa, Abdalaziz Elsaid Hamad, Seif Aldin Dawina Abdallah Faragallah, Mohammed Osman Hassan, Medani Ismaeil, Heba Abdalla Noureldeen, Alsammani Ali Mohammed, Elsayed Mohamed Elmustafa Osman, Mohamed Elnour Taha, Manal Awad Kheiry **(***2023***)**. Tapping Tools for Gum Arabic and Resins Production: A review Paper. *American Journal of Engineering and TechnologyManagement*. Vol. 8, No. 3, 2023, pp. 33-40. https://doi.org/10.11648/j.ajetm.20230803.12

[21] NAS. 1979. Fire wood crops: shrubs and tree species for energy production. Volume 1 and 2. Washington, DC: National Academy Press. pp 329.

[22] Nasereldin, M, Abdalla, Husein, S, Godan and Raddad, Elamin, Y (2008). Agroforestry for sustainable dry land farming in Southern Darfur. Proceedings of the 43th meetings of the Nation Crop Husbandry Committee, Wad Medani, 2008.

[23] Obeid, M. and Sef Eldin, A, (1970). Ecological studies of the Vegetation of the Sudan *Acacia Senegal* (L.) Willd and its natural regeneration, Journal of Applied Ecology, 7: 507-518.

[24] Oleghe, P. E, and Akinnifesi, F, K (1992). Nitrogen Fixing Trees. Research Reports Vol. 10.

[25] Ross JH. 1979. A conspectus of the African *Acacia* Species. Memoirs of the Botanical Survey of South Africa, No. 44.

[26] Sayeda, A. A. Khalil, H. A. El Atta and I. M. Aref (2011). Increased gum arabic production after infestation of *Acacia senegal* with *Aspergillus flavus* and *Pseudomonas pseudoalcaligenes* transmitted by *Agrilus nubeculosus*. African Journal of Biotechnology Vol. 10(37), pp. 7166-7173, 20 July, 2011.

[27] Seif El Din A. 1984. Agroforestry Practices in the Dry Regions, At-Tasahur, Vol. 2, 8-9.