JOURNAL OF FOREST PRODUCTS & INDUSTRIES, 2013, 2(6), 34-37, ISSN: 2325-4513 (PRINT), ISSN: 2325-453X (ONLINE)

Research Publisher
Discovery that Matters

RESEARCH ARTICLE

Gum Arabic (*Acacia Senegal* (L.) Willd) Viscosity in Relation to Rainfall and Soil Metal Ions

E.E. ElAmin[1], M. E. Blal [1], A. E. Mahmoud[1]
[1]Forest Research centre, Agriculture Research Corporation.
Soba, Khartoum, Sudan. Elamin.elhadi@gmail.com

(Received: October 25, 2013**; Accepted:** November 15, 2013**)**

Abstract—The aim of this study was to investigate the effects of site factors namely; soil types and rainfall on viscosity of gum arabic from (*Acacia senegal*) and relationship between gum viscosity and soil metal ions.. Samples of Gum Arabic and soils were collected from sites representing three main soil types viz (sand, clay and sandy clay or "gardud" under three rainfall (low, medium and high) conditions throughout the gum belt of North, South Kordofan and Blue Nile States. Gum viscosity and pH were measured. The soil samples analyzed to determined metal ions. Analysis of variance was used to determine the differences in metal ions, viscosity and pH of gums from different as sites affected by soils type and rainfall. Correlation analysis revealed high average viscosity for gums produced under low rainfall conditions in sand and clay soils, as well as also in gardud soil under medium rainfall. Sand in medium rainfall, gardud in high rainfall and clay in medium and high rainfall produced low average viscosity gum with significant differences between them and the above mentioned main factors. The results also showed that there were no significant differences in pH for all gum samples obtained from different soil types and different rainfall levels.

Index terms- *Acacia Senegal,* Gum Arabic, Rain fall, Soil type, Viscosity, metal ions.

I. INTRODUCTION

Gum arabic is one of the oldest and best known tree gum exudates and has been used as article of commerce for over 5000 years [1]. It is the exudates from certain *Acacia* trees, which occurs in a wide belt of tropical and sub-tropical, arid and semi-arid regions and is very drought resistant. Trees survive in the most adverse conditions, subject to hot winds and sandstorms on the poorest soils of rock and sand [2]. In the Sudan, *A. senegal* var. *senegal* grows in various environments ranging from semi-desert with under 100 mm rainfall to the fringies of the moist savanna with up to 900 mm rainfall and soils ranging from sand to heavy clays. It is found in pure stands or in mixture with other species [3 and 4].

The viscosity of Gum Arabic solution is affected by a number of factors which include age of parent tree, rainfall during the harvesting season, time of exudation and type of storage conditions. Thus viscosities of solutions of gum arabic of similar grades can vary by as much as more than 50% and are affected differently by concentration, temperature, pH, salt content and presence of other electrolytes [5]. Gum Arabic as found in nature exists as a natural or slightly acidic calcium, magnesium, potassium or sodium salt of complex polysaccharide[5] [6] and[7] reported that the different metal ions present in gum arabic molecules affect the Gum Arabic viscosity, where monovalent ions increase gum viscosity while divalent ions decrease it. However, research directed towards understanding the relationship between soil type containing these metal ions and rainfall to viscosity of Gum Arabic is lacking. Therefore, the main objective of this study was to investigate some of the main factors that affect gum viscosity such as variation in soil and climate factors.

The specific objectives were:

1. To determine the effects of rainfall and soil type on gum viscosity.
2. To determine the relationship between gum viscosity and soil metal ions.

II. MATRIALS AND METHODS

Gum and soil samples were obtained from three different provenances in different ecological zones of the gum arabic belt within three rainfall isohyets (high, low and moderate). The experiment was carried out in three types of soils of the *Acacia senegal* belt (Clay, "gardud" or sandy clay and sandy soil). Zone one lies in the clay soil with low rainfall (350-450 mm) was represented by Karkog area. Zone two and three were represented by Eldaly and Bout, in moderate (500-600 mm) and high (700-900 mm) rainfall isohyets, respectively. Elodaya, Elfula and Elmoglad in west Kordofan represent the low (250- 350 mm), moderate (400-500 mm) and high (500-

Crossponding author E mail: Elamin.elhadi@gmail.com

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600 mm) rainfall isohyets in gardud soils, respectively. The sandy soil area was represented by Bara, El Himaira and Babanosa for low (150-200 mm), moderate (250-350 mm) and high (450-500 mm) rainfall isohyets, respectively.

Nine hashab trees from each of the different areas were randomly selected, marked and tapped for Gum Arabic yield. The gum samples (81 samples) obtained from tapping the trees was dried under room temperature, grinded in blinder to be ready for preparation of gum solutions. Viscosity and pH of the different gum solutions were measured using Brookfield Viscometer (MYR viscometer-version L spindle 3, speed 200 rpm and pH-meter. Fifty four soil samples were collected for each forest from the same provenance place where the trees were selected and the samples were taken from 0-30 and 30-60 cm soil depth. The soil samples were kept in bags and sent to the soil laboratory of the National Council for Research (NCR) for general analysis of metal ions Potassium (K), Sodium (Na), Calcium (Ca) and Magnesium (Mg) according to the standard atomic absorption conditions using (Atomic Absorption Spectrometer, Model Buck scientific U S A, 2005) and also for determination pH.

The data were analysed using the statistical analysis system (SAS), JMP programs. Analysis of variance and Duncan's Multiple Rage tests at 0.05 probability level was used to study the significance of the differences between the mean of gum viscosity and soil composition from different locations of the gum belt. Also correlation analysis was done for viscosity and the different soil components.

III. RESULTS AND DISCUSSION

Table 1 shows the effect of soil type on mineral content. From this table it is clear that there was no significant difference in calcium and sodium contents between the different types of soils. For potassium contents there were no significant differences between sand and gardud soils, but these were significantly different ($p<0.05$) than clay soils. Magnesium content increased significantly ($p<0.05$) in gardud and clay soils as compared to sandy soil. From this information it is clear that Ca and Na are not affected by soil types while K, Mg are greatly affected by soil types.

Table 1. Effect of soil type on minerals content

Soil type	Ca	K	Mg	Na
Sand	2.279 a	2.279 a	6.269 b	2.130 a
Gardud	2.591 a	2.591 a	10.616 a	1.799 a
Clay	2.303 a	2.303 b	10.143 a	1.625 a
Probability	0.903	0.0002	0.047	0.578
SE±	0.544	0.233	1.327	0.345

The correlations between some soil physiochemical properties investigated for *Acacia senegal* in sand, gardoud and clay soils are shown in tables 2, 3 and 4. There were significant and positive correlation between soil Mg and soil Ca (r = 0.829, P<0.05) in sand (r = 0.794, P<0.05) in gardoud soil (r = 0.923, P<0.05) in clay and there were significant and negative correlations between soil pH and soil K in gardoud (r = -0.833, P<0.05).

Table 2. Correlation coefficient (r) between some soil physiochemical properties investigated for *Acacia senegal* in sand soils

Variable	ca	k	mg	Na	pH
ca	1.0000				
k	0.3297	1.0000			
mg	0.8294	0.5765	1.0000		
Na	0.0203	0.5248	0.3044	1.0000	
pH	-0.4535	-0.1858	-0.5692	-0.4374	1.0000

Table 3. Correlation coefficient (r) between some soil physiochemical properties investigated for *Acacia senegal* in gardoud soils

Variable	Ca	K	Mg	Na	pH
Ca	1.0000				
K	0.2902	1.0000			
Mg	0.7946	0.4368	1.0000		
Na	0.5675	0.0056	0.4541	1.0000	
pH	-0.1574	-0.8332	-0.3553	0.3159	1.0000

Table 4. Correlation coefficient (r) between some soil physiochemical properties investigated for *Acacia senegal* in Clay soils

Variable	Ca	K	Mg	Na	pH
Ca	1.0000				
K	-0.2303	1.0000			
Mg	0.9230	-0.2310	1.0000		
Na	-0.3393	-0.5915	-0.2587	1.0000	
pH	0.6070	-0.2517	0.5280	-0.4971	1.0000

Soil particle size distribution was determined in order to ascertain whether the soils under tree canopies of the three soil types were different. The soils under the variety canopy were predominantly sandy with sand accounting for more than 60% of the inorganic mineral components in the soil (Sandy and gardoud soil) table (5). [2] collected data for soil particle sizes in Northern Sudan for sole *Acacia senegal* system and *Acacia senegal* intercropped systems and reported that sand accou nted for more than 90% indicating that these varieties can grow well in sandy soils. The observed differences in the soil particle size distribution between the three sites are most likely due to the effects of the mineralogical differences between the parent materials across the site. These differences are often associated with different vegetation types, both of which can contribute to variation in soil pH and exchangeable cations [3]. However, the differences among the study sites indicate that the soil have been derived from different parent material under difference climatic conditions and topography.

Crossponding author E mail: Elamin.elhadi@gmail.com

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Table 5. Soil texture under *Acacia senegal* stand

Soil types	Sand (%)	Clay (%)	Silt (%)	Soil textural type
sandy	71.93	24.19	3.87	Sand clay loam
gardoud	58.94	31.82	9.55	Sand clay loam
Clay	16.66	54.35	28.96	Clay

Table 6 shows the relationships between rainfall and soil types. Low rainfall produced higher gum viscosity in all of the three soil types, while high rainfall gave an increase in viscosity in sandy soils with significant difference compared to other soil types. The moderate rainfall has a positive effect in viscosity of the gum produced in gardud soils.

Table 6. Effect of rainfall on pH and viscosity of gum in different soil types

Rainfall (mm)		Soil type	Viscosity/cps		pH	
High	(400-450)	Sand	68.88	a	4.76	a
	(500-600)	Gardud	56.66	b	4.64	a
	(700-900)	Clay	56.56	b	4.56	a
Moderate	(400-500)	Gardud	81.11	a	4.66	a
	(250-350)	Sand	55.56	b	4.75	a
	(500-600)	Clay	55.56	b	4.59	a
Low	(150-200)	Sand	85.56	a	4.83	a
	(350-450)	Clay	80.00	a	4.53	a
	(250-350)	Gardud	70.00	a	4.62	a

Table 7 shows the effect of edaphic factors and rainfall on viscosity. The gum produced under low rainfall soils (gardud and clay) were affected by the increase in sodium which is reflected in the increase of gum viscosity. The increase of calcium in sandy and clay soils under moderate rainfall decreased the gum viscosity while the increase in pH in gardud soils under moderate rainfall has increased the gum viscosity. An inverse relationship existed between viscosity and soil water saturation and direct relation with sodium content in clay soils under high rainfall, while in gardud high rainfall the relationship was direct with potassium content.

Table 7. Effect of edaphic factors and rainfall on gum viscosity

Rainfall	Soil type	viscosity	Ca	K	Mg	Na	pH	Sand%	Saturation
Low	Sand	High	0.89	-0.32	-0.25	-0.29	0.0002	-0.86	-0.70
	Gardud	High	-0.65	-0.59	-0.98	0.99*	0.94	0.95	0
	Clay	High	0.77	-0.62	0.43	0.99*	-0.69	-0.67	0.81
Medium	Sand	Low	0.99*	0.77	0.70	-0.92	-0.11	-0.67	0.86
	Gardud	High	0.68	-0.97	0.97	0.53	0.99*	-0.93	-0.13
	Clay	Low	0.99*	-0.86	0.40	0.97	-0.50	-0.94	0.86
High	Sand	High	0.89	0.30	0.81	-0.58	0.02	0.80	0
	Gardud	Low	0.54	0.99*	0.80	-0.01	-0.95	0.22	-0.0009
	Clay	Low	-0.29	-0.82	-0.83	1.00*	-0.86	-0.88	-1.00**

* Positive direct correlation at $P<0.05$

** Negative reverse correlation at $P<0.05$

It was proved by several studies that metal ions (Ca, K, Mg, and Na) affect the viscosity of water soluble gums. The soils in the Gum Arabic belt are all rich in Ca, K, Mg, and Na metals.

Crossponding author E mail: Elamin.elhadi@gmail.com

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These metal ions require an alkaline reaction of soil to be absorbed by the plant. Fortunately all types of soils included in this research have an alkaline reaction which will facilitate absorption by the tree.

Five sites out the of nine studied sites were found to have high gum viscosity that is significantly different from the other four sites, while the test produced lower gum viscosity. According to the results of this study the effect of metal ions seemed to be clear in increasing or decreasing the viscosity of the gum in most of the studied sites. Due to the high amount of sodium content in all the three types of soils in low rainfall areas, all these types of soils produced high viscosity gum. Gum from gardud soils in medium rainfall areas has high viscosity. The reason for that viscosity increase may be due to the high pH value as there was a significant correlation between pH and viscosity in these types of soil. This result also indicates that some unstudied factors such as age of the tree and management system might have some affects and can be considered for future studies. Moreover viscosity and soil sodium content under high rainfall in clay soils showed high correlation. In spite of the strong correlation between viscosity and high amount of sodium in clay soils under high rainfall, the gum produced by these soils has the lowest viscosity. Gardud soils under high rainfall areas produced low gum viscosity compared with gardud soils in other rainfall levels that produced high viscosity gum, despite the fact that a strong correlation exists between viscosity in this type of soil and potassium content.

IV. CONCLUSION

The study showed that Ca, K, Mg and Na are the main determinations of the gum viscosity of *A. senegal* var. Senegal. Gum produced from sand and clay soils under low rainfall and gardoud soils under medium rainfall have a high gum viscosity (85.56, 80.00 and 81.11 respectively). The soil characteristics within gum belt are major factors that influence the gum Arabic production and quality and further research is needed especially on the effect of soil micronutrients on gum quality. Further research is necessary to identify the provenances with high gum production and quality under the different agro-ecological zones within gum Arabic belt of Sudan.

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Crossponding author E mail: **Elamin.elhadi@gmail.com**