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Influence of Droughton *Acacia Senegal* (L.) Willd: Gum Yield within a Soil Moisture Gradient in North Eastern Nigeria

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ABSTRACT: There had been a discernible shift in climate affecting the Sahelian zone of northern Nigeria. This attribute of drought influenced the rate of gum Arabic production in the North eastern axis. Therefore, these called for the studied of the Influence of drought on *Acacia senega l*L.) Willd. Gum yield within a Soil moisture gradient in north eastern Nigeria. Two studied areas were purposively selected based on the availability (Gujba and Nguru). Complete Randomised Design was employed with three (3) samples examined at six (6) levels in six different tapping periods. Also, systematic line transect of 1Km was laid at the middle of both plantations where 1m by 1m transect were further laid in four transect sample plots. The soil samples were collected with the aid of soil auger at different levels (0–25 cm, 25–50 cm, 50-75 cm, 75–100 cm, 100–150 cm, 150–200 cm).Data was subjected using analysis of variance with statistical analysis system and descriptive statistic was also employed.The results showed that mean yield of Gum Arabic is Gujba is higher than Nguru (45kg and 30kg) respectively. Furthermore, physiochemical properties showed that pH, aluminium calcium and magnesium in both plantations were very high which is harmful for plantation development. Therefore, there is need for proper conservation and silvicultural management for both study areas.

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Acacia senegal (L) Willd is a leguminous multipurpose African tree species belonging to the family Fabaceae (Dorthe 2000; Kiondo, *et al*., 2014). It is a shrub or tree of small to medium size measuring up to 15m in height, prickly and deciduous (Maundu*et al*., 1999; Booth and Wickens 1988). *A. senegal* are widely distributed in the arid and semi-arid regions of Nigeria, and has an enormous ecological and economic importance value for its gum, fodder and timber (Traoré*et al.*, 2012).In Nigeria, high concentrations of cultivated and natural stands of grade one gum Arabic (*A. senegal*) are predominantly found in north-eastern states around latitude 10º 30º N and above (Ojiekpon and Aghughu, 1997). The Nigerian production figure for 2010 was estimated at 34780 tons (UNCTAD, 2013). A ton of Nigerian raw gum Arabic is valued between USD 1 550 and 1 650. World exports of crude gum Arabic originate primarily from Africa. The major producing countries are Sudan,Chad and Nigeria. The volume of international trade on gum Arabic ranges from 90,000-120,000 tons/annum (ITC, 2011). The European Union (EU) is the largest market (FAO. 2010).The precursors, enzymes and pathway of the biosynthesis of GumMaterials are not precisely known. Although, the phenomenon of Gum formation termed "*Gummosi*" occurs in the cavities (Gum ducts) localized in the bark of *Acacia Senegal* (Falu, 1982). The cambium is involved in the formation of the special group of parenchymatious cells, which subsequently form gum duct when gummosis starts. Gum formation therefore result from the metamorphosis of the organized cell wall materials into unorganized amorphous substances, which is the gum (Brown *et al***,** 1952). Starch is the major ingredient utilized as source for gum formation. Greater amount of gum formation is induced by harsh environmental conditions. Hence, the tapping of Gum Arabic usually commences at the end of the raining season and during on-set of hamattan period, Oct.-March (Odo, 1994).Gum Arabic production is a physiological process and as such physical factors including atmospheric temperature and soil moistures, soil physical properties and altitude, affect yield and quality (Wekesa, 2009). Gum Arabic yield is highly affected by rainfall (Ballal *et al.*, 2005a). In a study in Sudan (North Kordofan) the authors showed that annual rainfall received in the season immediately preceding tapping strongly and positively affect the gum yield. Dione (1996) also reports a positive correlation between annual rainfall and gum production over a seven year period in the Senegalese Sahel. Oleghe and Akinnifesi (1992) showed that an adequate water supply significantly affects the production of gum in the dry season. In a similar study

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in Demokeye western Sudan, Ballal *et al.,* (2005b) found that gum Arabic yield was positively correlated to rainfall and temperature. Furthermore, significant variation was observed in gum yield from different local provenances in Sudan (Harmand *et al.,* 2012; Raddad and Luukkanen 2006). The aim of this study isto investigate the effect of drought stress on *A. senegal*, Gum yield within a Soil moisture testing different physiological and morphological growth parameters, and to find out if there are differences between provenances.

MATERIALS AND METHODS

Description of the study area: The investigation was carried out in two locations Nguru and Gujba provinces of Yobe state North Eastern Nigeria with a naturally occurring moisture gradient. The northern site, Nguru (12.53°N, 10.28°E alt. 343m) is classified as arid, associated with Sahel savannah and scrub vegetation zone.The climate is characterized by a distinct long dry season with no rain between October and May, and a rainy period occurring from June to September, the rainfall lasts between 80 to 100 days with annual drops ranging between 200mm to 500mm, with average temperature during the hottest periods of the year recording over 40°C.Soil type of the area is sandy loamy and clay, while the southern site, Gujba (11.30°N, 11.56°E alt. 456m) is classified as semi-arid, associated with Sudan savannah vegetation zone.The climate is characterized by a distinct dry season with no rain between November and April, while the rainy period occur from May to October with an annual drops ranging between 300mm to 500mm, lasts 120 to140 days, the average temperatures during the hottest periods of the year is 35°C. The soil is loamy sand (Jibo *et al.,* 2018; Hess *et al.*, 1995).

Soil sample: Soil samples were taken from a pit at each site (Nguru and Gujba) at different depths (0–25 cm, 25–50 cm, 50-75 cm, 75–100 cm, 100–150 cm, 150–200 cm). Undisturbed soil sample was collected by means of metal core sampler for complete soil analysis using the cylinder soil method (Blake and Hartge 1986). Soil volumetric water content was measured at 125 cm depth using a calibrated soil moisture probe Type PR2 (Delta T Devices, Cambridge UK) with four rods of 60 mm length and was recorded monthly.

Sample collection: In the first year the first gum picking took place 45 days after tapping and each consecutive picking was collected after 15 days from harvest of the previous one. Tapping was carried out by specially designed tool, called a "sunki". This has a metal head fixed to a long wooden handle. The pointed end of the head was pushed tangentially into the stem to penetrate just below the bark, and then pulled up to strip a small length of bark longitudinally from the wood which involves tapping of gum Arabic trees three weeks of rain stoppage. Damage to the wood was minimal as it was tested 6 periodic levels (1st and 15th of Sept. 1st and 15th of Oct. and 1^{st} and 15th of November), in each, three (3) trees will be tapped making a total number of thirty-two (32) for the season, such that eighteen trees (18) were tapped at each of the locations, namely Nguru and Gujba provinces.Humidity and Temperature were measure and store using Lascar EL-USB-2 Dew Point, Humidity, temperature Data Logger UK.

The gum from each picking weighed after drying using sensitive balance. Complete Randomized Design (CRD) was used for this study with three (3) treatments and six (6) levels making eighteen (18) samples in each plantation.

Hypotheses: The hypotheses being tested in this study will be: H_1 Gum Arabic yield will be related inversely to soil moisture availability and that, H_2 there will be significant variation in Gum Arabic yield from the northern and southern provenances.

Data analysis: Data was analyzed using Analysis of Variance (ANOVA) with Statistical Analysis System (All analyses were performed using the statistical software MINITAB® Release 16.12.0. and Sigma Plot® Release 12.0).) Computer package at 5% level of significance to determine differences in the treatment effect.

RESULTS AND DISCUSSION

Physiochemical Properties: Table 1a and 1b, shows soil particle distribution and soil chemical properties at different soil depths at the Gujba and Nguru experimental sites, respectively. Generally higher clay content was found at Gujba. Sand content increased with increasing in soil depths at the Gujba site. Silt content increased with depth at the Nguru site. The study of physicochemical properties of topsoil and subsoil in Gujba and Nguru revealed a strong influence of the tree, environmental factors and litter fall production. It was discovered that the topsoil properties; sand silt, clay and soil pH similar within the forest reserves. There were also similarity in the other soil nutrient properties; carbon, nitrogen, phosphorus, potassium, sodium, calcium, magnesium, cation exchange capacity and organic matter arising from the effect of many factors. The physical properties were found to be normally distributed. Sand in Gujba was increased with the ranged between 44%-60% while in Nguru the range decreased along the profile from 81% -59%. In Gujba and Nguru, the silt was ranged 18%-20% and 9% - 21% respectively. Also, clay soil found to be higher in Gujba than Nguru with the value 37.7%-19% and 9.5%-19.7%.

Table 1a. Profile Characteristics and Condition on Gujba Plain

Profile Depth (cm)	Texture (%)			Textural class	pH water	EC (mS/cm)	Exchangeable cations (meg/100g soil)					ECEC %	B.S	Total N	Org.C	P(µmg/g)
	sand	silt	clay				Ca	Mg	K	Na	$H^{+} + Al^{3+}$					
0-11	44.3	18	37.7	CL	6.1	0.08	1.8	0.3	0,31	0.13	0.64	3.28	80.3	0.02	0.4	4.8
11-52	46.2	16	37.8	CL	5.3	0.04	0.7	0.8	0.21	0.14	2.55	4.4	42.1	0.03	0.6	2
52-89	46.2	14	39.8	CL	5.5	0.05	1.3	1.4	0.1	0.15	1.1	4.05	75.8	0.03	0.52	4
89-114	52.2	16	21.8	SCL	6.2	0.05	2.2	0.9	0.12	0.21	0.75	4.18	82.1	0.02	1.22	1.22
114-161	60.2	20	19.8	SCL	6.7	0.06	2	0.9	0.15	0.24	0.6	3.89	84.6	0.02	0.76	2.5

Table 1b. Profile Characteristics and Condition on Nguru Plain

Profile Depth (cm)	Texture (%)			Textural class	pH water	EC (mS/cm)	Exchangeable cations (meg/100g soil)					ECEC%	B.S	total N	Org.C	P(µmg/g)
	sand	silt	clay				Ca	Mg	K	Na	$H^{+} + Al^{3+}$					
0-13	81.5	9	9.5	SL	6.2	0.08	1.7	0.3	0.32	0.13	0.64	3.26	79.5	0.02	0.4	4.7
13-47	65.2	16	18.8	SL	5.2	0.04	0.7	0.8	0.22	0.14	2.55	4.4	43.2	0.03	0.6	2.1
47-78	67.4	15	17.6	SL	5.6	0.05	1.2	1.4	0.11	0.15	1.1	4.05	71.6	0.02	0.52	4.1
78-111	62.2	16	21.8	SCL	6.3	0.05	2.3	0.9	0.12	0.21	0.76	4.18	82.1	0.02	1.22	1.22
111-174	59.3	21	19.7	SCL	6.8	0.06	2	0.9	0.16	0.24	0.61	3.89	85.5	0.02	0.76	2.7

Table 2. Saturated Hydraulic Conductivity (cm/hr) of Surface and Subsurface Soils of Plain sites.

Soil layer	Site	Mean Hydraulic Conductivity
Top soil	Nguru	2.33a
	Gujba	1.88
Sub soil (0.75m)	Nguru	2.1
	Gujba	2.68a
Sub soil (1.5m)	Nguru	1.86
	Gujba	1.26

Means with the same letter subscript are not significantly different.

Table 3: Two-way ANOVA: Gum versus provinces

Source	DF	SS	MS	F	P
Provinces	1	1032.12	1032.12	10.47	0.003
Treatment	1	31.21	31.21	0.32	578
Interaction	1	163.84	163.84	1.66	0.206
Error	32	3153.47	98.55		
Total	35	4380.65			

S = 9.927 R-Sq = 28.01% R-Sq(adj) = 21.26%

Post hoc analyses were performed using Tukey 95% simultaneous confidence intervals all pairwise comparisons among levels of provenance. DF =degrees of freedom, Prov =provenance. Variable = Gum versus provinces, Treatment

This showed that the profile 1 to 3 were clayish in nature (Table 1a). Both provenances showed the increase with the value of pH ranges from 6.1-6.7% and 6.2-6.8% respectively. This implies that both provenances are acidic in nature. The soils are acidic as a typical of most soils in the savannah area derived from acid sands of Nigeria (Ubi *et al.*, 2013).

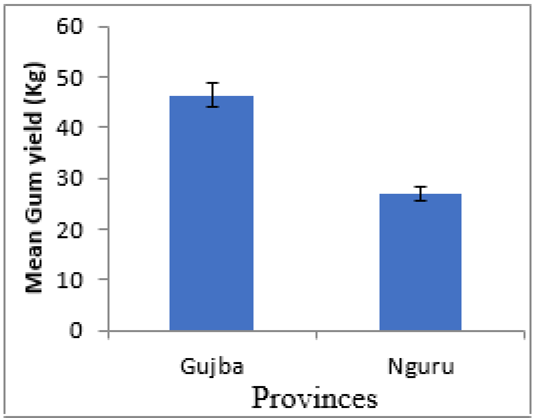

Fig 1. Mean (±SE) Gum yield of *A. senegal* in Nguru and Gujba. There was a significant difference of (P=0.003) between provenances, indicating that Gujba provenances had the highest gum yield.

The higher pH could be attributed to the presence of pebbles and small rocks. In Gujba and Nguru, organic carbon ranged from 0.40-076% and 0.41-0.76% (Table 1a and table 1b). Both later and former had the same organic carbon status. This attributed to the rate of falling litter and decomposition wish were proved to be the equal Salami *et al*., (2020). The organic material serves as an energy source for soil microorganism, the bulk of which comprises fungi and bacteria (Isaac, 1993).The large variation in pH values of the soils is tied up with range in values of exchangeable bases and aluminums oxide. Generally, the pH values reflect the trend in highly weathered soils elsewhere in the Semi-deciduous ecological zones (Isaac, 1993). The data on the exchangeable calcium were normally distributed. Calcium ranged from 1.8 – 2.0 cmol (+)/kg and 1.7-2.0mol (+)/kg respectively. The mean exchangeable magnesium followed the same trend with range from 0.3-0.9cmol (+)/kgin both reserves. Most of these values were high because they were more than 0.3 mg/kg, considered average for most Nigerian soils (Sobulo, 1999; Lombin, 1973). The Available P in the two provenances varies across the profiles. Upper layers had the highest percentage compared to other profiles in both reserve. Available P content is lower in all the soils across the profiles in the two provenances compare to the optimum value of between 25 and 36 ppm for tropical soils (Dean and Olson, 1965). The finding showed that total nitrogen was very small with constant value of 0.02 mol (+)/kg except in profile 2 in both provenances. This agreed with findings of Ferreri *et al.*, (2019) who stated that upper layer of the soil (0-10cm) presented larger amount of organic matter, C, N showing that as the depth increased the concentration of these variables interfering in the amount of the SOM

Saturated Hydrraulic Conductivity: The saturated hydraulic conductivity, Ks of Gujba ranged from 1.86 to 2.33cm/hr. The ranges in Ks for Nguru ranged from 1.26-2.86cm/hr respectively (Table 2). The highest Ks observed in Gujba at sub soil (0.75m) Thus, the Ks of Gujba was rapid at subsoil 0.75m while Nguru was rapid moderately at topsoil. The test also revealed that for the top soil and subsoil at (0.75m) there were significant different Gujba and Nguru while Subsoil at 1.5m showed no significant different between the two sites (Table2)

Gum Production: The study has been conducted on Influence of drought on *A. senegal* (L.) Willd. Gum yield within a Soil moisture gradient in north eastern Nigeria. The finding showed that there was significant different between the two provenances. This is in accordance with finding of Ilu et al., (2020) that there is a significant difference in the production of Gum Arabic in Kadoma and Kwanar Duhuwa plantation. This may be due to the responses of *A. senegal* to drought across a moisture gradient which demonstrated that there were differences in the pattern of growth between Nguru and Gujba provenances for this species (Jibo and Barker 2020; Jibo and Barker 2019). Furthermore, there was also significant different in the interaction between the provenances and treatments. However, the treatments showed no significant different.

Conclusion: Physical and Chemical characteristics of top and subsoil indicated a strong influence of canopy, litter fall decomposition and other environmental factors. The result showed that the chemical properties were very high resulting in low fertility. These characteristics might influence the physical outlook of trees and gum yield. However, it is noteworthy that some environmental variables might have influenced the activities of the decomposer and also some soil characteristic such as high acidity directly might affect the process. Therefore, there is need for proper soil conservation and silvicultural management for both study areas.

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