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EFFECT OF STAND TYPE AND TREE SIZE ON GUM ARABIC YIELD AND SEED CHARACTERISTICS OF (ACACIA SENEGAL) IN NORTH KORDOFAN STATE, SUDAN

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ABSTRACT
To study effect of stand type and tree sizes on gum arabic yield of *Acacia senegal* tree species, two locations of local villages in Sudan, called Demokeya a reserved research testing site east Elobeid town and Al-Rahad natural open forest had been selected inside gum arabic belt. Two sizes (base on stem diameter at breath height of the trees) were determined within these two forests. A combination of four variables was considered as source of variation to be tested for gum yield and seeds production. Every experimental level was represented with (5 trees). Seeds and gum arabic yield were collected from these combination groups separately, seeds were measured and gum was weighed. The data obtained subjected to statistical analysis using (SAS) a computer software program. The result showed a highly significant differences on fruits width and length ($p = 0.001$) and significant different on seed/fruits ($p = 0.05$). Variation within the number of seeds per pods and the variation within the number of seeds per pods of *Acacia senegal* revealed that trees of Demokeya size-2 (6-10 cm) showed highest significant difference in number of seeds per pod (5.2 seed/fruit). The result also showed significant differences at significant level ($P = 0.01$) on gum yield for size class, in the both sites, size class (2) was higher gum yield all around fifth pickings for Demokeya and Al-Rahad areas.

KEYWORDS: Gum Arabic, Demokeya, North Kordofan, Hashab tree and *Acacia senegal*.

1. INTRODUCTION

Changes to disturbance regimes associated with climate change and human activities are likely to have dominant and far-reaching effects on natural ecosystems.[1] *Acacia senegal* L. (Willd) is the multi-purpose tree with important environmental and economic role produces a strategic commodity.[2] It produces gum arabic, the tree stabilizes sand dunes, fixes atmospheric nitrogen and is a source of fence posts, firewood charcoal and fodder.[3] The species extends over a wide ecological range that differs in rainfall, soil types and altitude.[4] Sudan has emerged as one of the dominant producers of gum arabic; it has wide belt of *Acacia senegal* trees. Sudan contributes to about 95% of the total world gum arabic production.[5] It effectively controls almost over 80% of the world market.[6,7] The Sudan is aware of *Acacia senegal* tree as a national wealth, which needs to be conserved, improved and developed; not only to provide a sustained yield of gum, but also for other important socio-economic benefits of protection and production.[8]

The gum arabic tree (*Acacia senegal* (L.) Willd, locally known as (Hashab) occur on clay and sand soils in natural belt extending between latitudes 10˚ and 14˚ N. Within this zone *A. senegal* tree is found grown under rainfall between 280-450mm and 500mm and above in sand and clay soils.[9] Variations in yield are expected to be found between species, varieties, and size and age classes and across different geographical regions.[10] Moreover, climatic conditions, edaphic characteristics and genetic differences are all expected to cause variations in yield between the same species located in different geographical regions.[11] There is a positive relationship between gum yield, rainfall, temperature, tapping date and intensity.[12] There is also variation of seed collected from different sources.[13] Apart from drought, desertification and mismanagement, gum arabic production also varies due to complex factors in physical and biological aspects and socio-economic environments.

The misuse of land, climate change, drought and desertification is considered to be among the main factors that have led to fluctuations in gum arabic yield and the consequent instability of supply[14] The effect of all or some of these factors has impact on gum arabic production.[15] Plants in arid zones are usually subjected to a series of drought stresses where rainfall is variable and erratic and frequent cycles of drought naturally occur. However, trees follow different tactics to survive by drought avoidance and drought tolerance mechanisms.[16]

This experimental study is aims to assess the effect of soil and tree size on gum yield, seed characteristics of (*Acacia senegal*) in North Kordofan State.

2. MATERIAL AND METHODS

Study area

Two gum areas were identified in the North Kordofan states Demokeya plantation reserved forest and Al-Rahad natural Hashab forest. *Acacia senegal* gums and seeds were collected from trees that were identified, depending on the size of the diameter, and they were collected in the season of tree seed maturity.

Table 3.1: Location of target areas of the experiment.

Gum and Seed sources	Latitude	Longitude	Altitude (m)	Rainfall (mm)	Temp. (C^0)	
					Max	Min
Demokeya	13^o 11' N	30^o 12' E	560	358	35	20
Rahad	12^O 45' N	31^O 12' E	490	400	36	16

Layout of the experiment

The treatment combination (4 levels) of two sites and two tree size classes were arranged in to (RCBD) with three replications. Every experimental unit was represented with (5 trees) the total numbers of the trees were 20 trees (5X4). However, (60) *Acacia senegal* trees were determined and demarcated from the forest of Demokeya and Al-Rahad, 30 for each site, and they were divided into two categories, the diameter of which is limited between (0-5) and (6-10).

Fruits collection

Acacia senegal (Hashab) fruits (pods) were collected separately according to the categories and locations. Seeds per pods were calculated and the dimensions of seed were measured (length and width). The seeds were extracted and subjected to laboratory seed testing (purity, number of seeds, moisture content, and viability), and germination test was conducted on the pure seeds.

Gum picking

After the trees were tapped at the beginning of October 2020, the gums were harvested (45 days from date of tapping) on mid-November and continued to mid-January, every 15 days, five pickings were determined, each sample of gum product was weighted.

Data analysis

The data analyzed by using SAS statistical software version 6.12 (SAS Institute Inc., 1996) for ANOVA table, while LSD test used for means separation of the results.

3. RESULTS AND DISCUSSIONS

Characteristics of *acaciasenegal* Seeds and Fruits

According to the (ANOVA) table presented in Table (1), the result of seeds and fruits characteristics of *Acaciasenegal* among different trees sizes from Demokeya and Al-Rahad areas, showed a highly significant differences on fruits width and length ($p = 0.001$) and significant different on seed/fruits ($p = 0.05$). Variation within the number of seeds per pods of *Acacia senegal* in Table (4.2) revealed that the trees of Demokeya size-2 (6-10 cm) showed the highest significant difference in the number of seeds per pod (5.2 seed/fruit). While Al-Rahad size-2 (6-10 cm) came in the second level (5.1 seed/fruit). In general size class (2) was higher seeds per pod than the small trees (size class 1). The least of seed per fruit was significantly obtained by Al-Rahad size-1 (0-5 cm), followed by Demokeya size-1 (0-5 cm) (4.7 and 4.6 seed/fruit) respectively (the same table). This result could be attributed to the level of maturity; small size of stem is related to some extend or usually -in terms of tree increment- to small tree because trees grow through increases in its height and the diameter of the stem. Growth refers to an increase in stem dimensions with time and is implicit in the expected continual increase in the tree stem dimensions.[17] This result is well stated by.[18] that Cone and seed production increased steadily with age or basal area at both the tree and stand level.

Table 4. 1: ANOVA table characteristics of *Acaciasenegal* Seeds and Fruits with different diameters from Demokeya and Al-Rahad areas.

Sources	Df	S.S.	M.S.	F-Value
Seed/fruit	3	7.4	2.5	3.4^{*}
Width	3	8.7	2.9	20.7^{***}
Length	3	83.1	27.7	16^{***}

Table 4.2: Characteristics of *Acacia senegal* seeds and fruits with different diameters from Demokeya and Al-Rahad areas.

Sources	Seed/fruit	Width (cm)	Length (cm)	Seed area
Demokeya (0-5)cm	4.6^{C}	2^{B}	8.7^{B}	17.4^{B}
Demokeya (6-10)cm	5.2^{A}	2.3^{A}	10.5^{A}	24.15^{A}
Al-Rahad (0-5)cm	4.7^{BC}	1.8^{C}	8.8^{B}	15.84^{BC}
Al-Rahad (6-10)cm	5.1^{AB}	1.6^{C}	8.4^{B}	13.44^{C}

Seed testing

Testing the seeds of the forest tree is necessary to evaluate the planting value of seeds and to achieve the some objectives for minimizing he risks of planting low quality seeds, determine the quality i.e. suitability for planting, identifying seed quality problems and their probable cause and determine the need for drying, processing and specific procedures to be used for gum tree.

Purity test of *Acacia senegal* seeds

Figure (4.1) shows the purity test of the seeds of Demokeya and Al-Rahad areas, the results showed that there were clear differences between the different sites, Damokeya seeds appeared to have observable differences compared with Al-Rahad seeds. Damokeya forest is governmental testing site belong to Elobeid Agricultural Research Station, the site has well trained and skilled labors and workers (farmhand) whom are well expert in seeds handling, and the method of tree seeds collection, whereas for other site (Al-Rahad area) they depend on the wage earner as hired hand labors. Proper seed handling techniques are necessary for successful reforestation efforts.[19] It said by the same author that "there is good reason to be as efficient as possible with tree seeds".

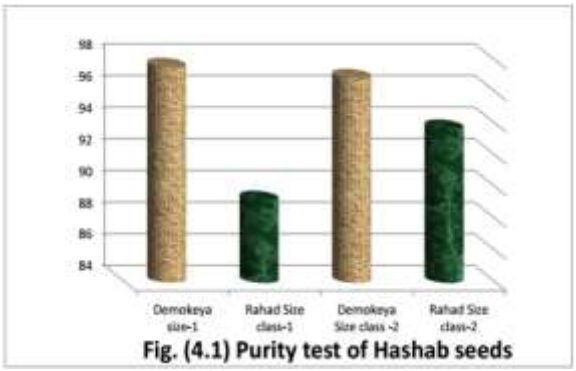

Fig. (4.1) Purity test of Hashab seeds

Number of seeds per kilogram of *acacia senegal* seeds

Determination of thousand-seed weight is an essential part for the estimation of the number of seeds contained in one Kilogram (Kg). This parameter helps the determination of the appropriate weight of seeds needed for the production of a certain number of plants and could reduce the cost of the seed purchase. Figure (4.2) shows the number of seeds per kilogram of seeds collected from Demokeya and Al-Rahad areas, in which Al-Rahad seeds gave the highest level compared to Demokeya seeds. The thousand-seed weight, as well as, the number of seeds per kg of the examined seed lots presented in the same figure Demokeya showed lower weight of seeds. It was stated by[20] that seed weight is a function of seed size, moisture content, and proportion of full seed in a given lot, and therefore it also gives an indication of seed quality. The thousand-seed weight is required for calculating sowing rate; the result showed that Al-Rahad appears high number of seeds per kilogram. This is attributed to the presence of high moisture content in the site.

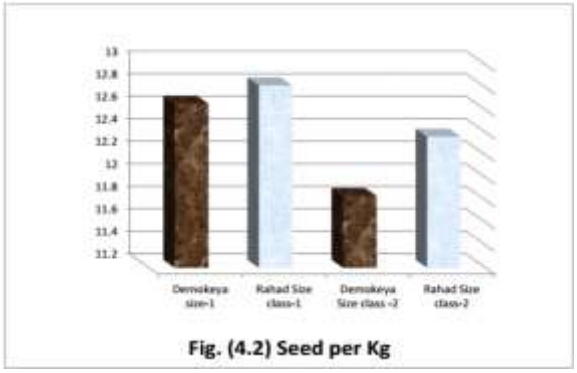

Fig. (4.2) Seed per Kg

Moisture content of *acacia senegal* seeds

Figure (4.3) shows the moisture content test of the seeds of Demokeya and Al-Rahad areas, the results showed that there was high moisture content of Al-Rahadsize-1 (6%), followed by Al-Rahadsize-2 (5.8)%. The semi-clay soil supplies the plants with more water which affects the moisture content of the seeds. Shallow water table of Al-Rahad cloud however, be one of the reason beyond the moisture of the seeds, however, Demokeya is dry area the seeds is supposed to be low moisture content. The importance of moisture of seeds was reported by many different authors; the initial seed moisture content plays a significant role and interacts with chilling temperatures or the rate of imbibition regulating the extent of the damage.[21] Imbibition damage was avoided after adjustments to increase seed moisture content by their exposure to humidified conditions[22] chilling temperatures usually promote lower levels of damage to seeds of higher initial moisture content.[22]

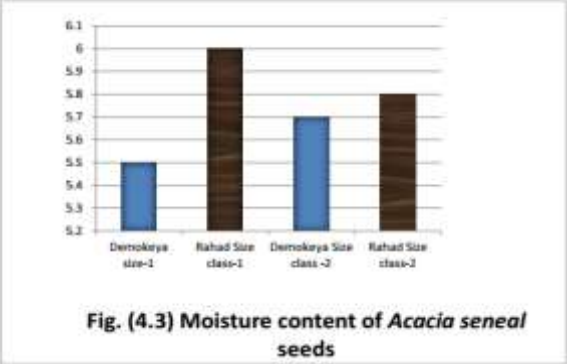

Fig. (4.3) Moisture content of *Acacia seneal* seeds

Viability test of *acacia senegal* seeds

Figure (4.4) shows the viability of the seeds, which explored a remarkable variation in the seeds according to their origin or tree size classes. Whether seeds are to be sown for crop production or stored in gene banks, information about their viability is very valuable.[23]

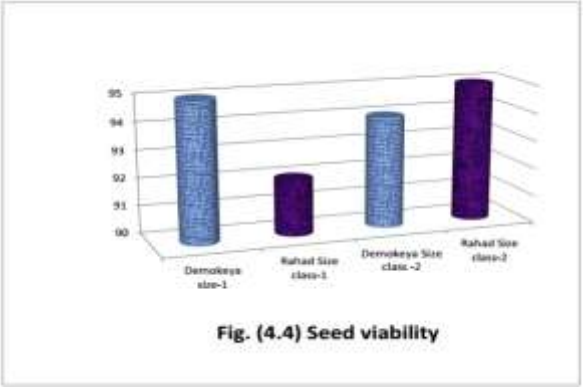

Fig. (4.4) Seed viability

Germination percentage of *acacia senegal* seeds

The result of the germination percentage of Hashab seeds of Demokeya and Al-Rahad areas is presented in Figure (4.5). There were no clear differences between the four sources of treatment at germination level.[24] stated that; the activation of metabolic machinery of seed embryo is the first and foremost step to initiate the seed germination process Thus, seed germination is the process of reactivation of the metabolic activity of the seed embryo, resulting in the emergence of radical (root) and plumule (shoot), thus leading to the production of a seedling or a young plant. However, germination is not generally possible for mature seeds because they are generally dormant. They need to undergo a post-maturation phase, called after-ripening, a period that allows them to acquire the capacity to germinate. The transition of dry seeds from dormant to non-dormant state corresponds to determinant physiological changes from arrested to permissive processes leading to germination. The characterization of possible chemical reactions and subsequent physiological activity at dry state remain the most difficult question in seed biology because experimental procedures require short- or long-term hydration. Yet, this question is crucial in the understanding of dormancy alleviation, germination, and longevity.[25]

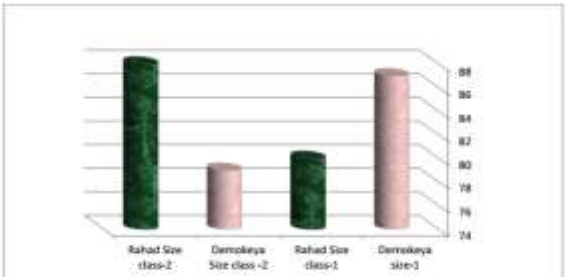

Fig. No. (4.5) Germination (%) of *Acacia senegal*

Gum yield with emphasis to Site and Tree size class

Analysis of variance presented in Table (4.3) showed significant differences (P = 0.01) for gum yield at Demokeya and Al-Rahad. The yield separated in to 5 pickings, the picking period of gum yield is 15 days. The result showed significant differences at significant level (P = 0.01) for size class, in the both site size class (2) was higher gum yield all around the fifth pickings for Demokeya and Al-Rahad areas. What is evident in this table that large tree exudates more gum compared to small if the diameter represented the age of the tree. Parameters influencing gum yield such as tapping techniques and soil mineral elements had earlier been investigated while there is dearth of information on effect of morphological characteristics on gum yield. This result is typically in line with[26] who reported that influence of tree physical characteristics such as heights and girths have been widely used in yield estimates in forestry where timber yield in volumes or logs of round wood draws heavily from information gotten from height and diameter at breast height (dbh). These parameters could also be used to estimate gum yield or yield of exudates of any tree species approximately.[26] also mentioned in their study that, Acacia *senegal* L. (Willd) is a multipurpose sub-Saharan tree species from which gum Arabic is collected. The term gum Arabic is used with varying definitions by different groups of people. It acquired its name because the early traders were Arabs.[27] In the context of its use as a food additive, the most current international specification published by[28] defines Gum Arabic as the "dried exudation obtained from the stems and branches of Acacia senegal L. (Willdenows) or closely related species. The same author in his study found that the yield increased along with increasing girth class, with maximum yield occurring at girth class >54c. It means that if the girth continues to increase at a constant tree height of <2.0m, yield would be increasing. Height in that case does not influence yield but tree girth does, increasing tree girth would therefore bring about increase gum production. Larger tree girth appears to favor the extension of the laticiferous layers where latex is stored.

Table No. (4.3) Gum yield with emphasis to site habit and tree size class

Treatment	Picking periods					
	1st pick	2nd pick	3rd pick	4th pick	5th pick	Total
Demokeya diam-1	41.73	46.19	31.4	12.53	14.05	145.9
Demokeya diam-2	**53.10**	**54.80**	**34.93**	**16.93**	**26.53**	**186.29**
Al-Rahad diam-1	35.93	27.03	18.23	15.23	13.80	110.22
Al-Rahad diam-2	**58.63**	**57.27**	**31.63**	**35.07**	**29.17**	**211.77**
Mean	59.85	45.57	29.05	19.94	20.87	
±SE	18.44 ns	4.97 *	2.67 *	4.89 *	3.84*	

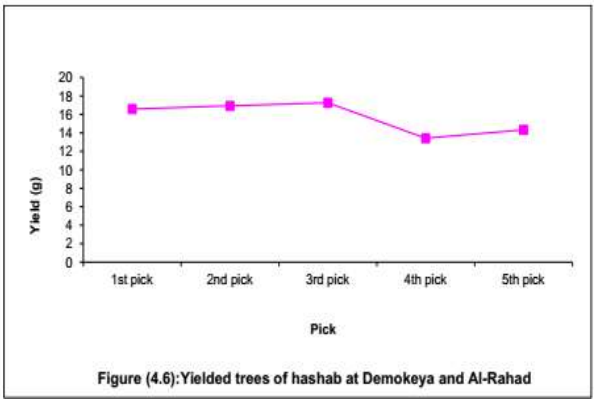

Figure (4.6):Yielded trees of hashab at Demokeya and Al-Rahad

The average production of gum 166.6 g per tree planted in the Demokeya area are (166.6 and 161 g per tree 66.64 and 64.4 Kg per ha respectively) the trees of Al-Rahad area can reach higher than that in better rainy conditions. This corresponds to,[29] heavy rains during the rainy season proceeding the established dry season. Plantation areas are a sources of high gum productivity, said.[30] The production of gum Arabic is the most important commercial product of *Acacia senegal*. Available evidence indicates that water stress is one of the factors that stimulates gum production,[31] and as different production performance in locations and size of trees has also been demonstrated this is to be expected their differences in gum production. Evidence also indicates increased gum yield in the first and second pickings. Moreover, the gum yield for each tree was very high in this study, averages ranged between (166.6 g) for Demokeya and 161 g for Al-Rahad tree. Apart from drought, desertification and mismanagement, gum Arabic production also varies due to complex factors in physical and biological aspects and socio-economic environments, these have impact all of them or some of these factors on gum Arabic production (12), (14) and (15).

Yielded trees of *Acacia senegal* Gums at Demokeya and Al-Rahad

In this experimental study every experimental unit was represented with five trees, these trees some time is not all of them exudates gum but the mean is calculating from the only yielded trees. These yielded trees were calculated and subjected to analysis of variance, Table (4.4). shows the results of these yielded trees, a highly significant differences was revealed in the second pick of the number of trees yield in the different sites, however, Demokeya size-1 showed the highest significant difference (19.33) g, followed by the Demokeya size-2 (17.67) g, while there were no significant differences in the number of trees from which gums were collected in the other picks. With these results, it was found that Demokeya site was better than the Al-Rahad site in the number of productive trees, and this is attributed to the fact that the sandy lands are more productive in the number of productive trees compared to the trees of the Gardud or clay soil.

Table No. (4.4) Yielded trees of Hashab at Demokeya and Al-Rahad areas

Treatment	Yielded trees				
	1st pick	2nd pick	3rd pick	4th pick	5th pick
Demokeya diam -1	18.33	19.33	18.00	13.33	15.00
Demokeya diam -2	15.33	17.67	18.33	12.33	17.00
Al-Rahad diam -1	16.33	14.67	16.00	13.00	12.00
Al-Rahad diam -2	16.33	16.00	16.67	15.00	13.00
Mean	16.58	16.92	17.25	13.42	14.33
±SE	0.98 ns	0.54 **	1.10 ns	2.64 ns	1.25 ns

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

- ✓ This experiment was targeted evaluate two essential parameters concerning *Acacia senegal* tree (seeds) and its valuable product (gum arabic). Two sites were identified and two sizes of (Hashab) trees were determined, the size was considered by stem diameter at breath height (dbh). Testing of the seeds is necessary for evaluating the planting value of seeds and to achieve the following objectives for

minimizing the risks of planting low quality seeds: - To determine the quality i.e. suitability for planting, to identify seed quality problems and their probable cause, to determine the need for drying and processing and specific procedures to be used, to determine, if seed meets established quality standards or labeling specifications and to establish quality and provide a basis for price and consumer discrimination among lots in the market.

- ✓ After the samples are received in the laboratory, it was first entered in a register and assigned laboratory test numbers and code, which is used in all subsequent analysis. The submitted sample was divided to obtain working samples required for various tests either by mechanical divider, random cups, and spoon or by modified halving method.
- ✓ The working samples weight for purity analyses and were calculated to contain at least 2500 seeds, but subject to a maximum of 1000 g. for sample weight. Each working sample is separated into two fractions: the selected component and the rest component. Both fractions are weighed and the weight of the former was calculated as a percentage of both together.
- ✓ All important seed testing was conducted on the pure sample, these tests were; purity test, number of Seeds per kilogram of *Acacia senegal* seeds, moisture content of *Acacia senegal* seeds, and viability test of *Acacia senegal* seeds.
- ✓ The germination testing was conducted from the pure seed fraction sample, to obtain information with respect to the planting value of the seed and to provide results which could be used to compare the value of different seed lots. A minimum of four hundred seeds are required in four replicates of 100 seeds each or eight replicates of 50 seeds each.
- ✓ The same Hashab trees which the seeds were collected from it were also subjected to tapping mechanisms for testing gum yield according to the source of variation between plantation forest stand and natural forest stand of *Acacia senegal* tree species. Tree were tapped using the new developed tools (Sonki) through removal of stem or branch bark of Hashab tree. The gum begin to exudates after tapping, gum was collected when it reach considerable size after 45 days from tapping.
- ✓ The result of the experiment showed significant difference for sources of variation on seeds characteristic and gum arabic yield.

4.2 Recommendation

- ➢ To ensure good seeds quality and stocked seedling, seeds shall be tested for normal seedlings, abnormal seedlings, hard seeds, fresh un-germinated seeds and dead seeds.
- ➢ Germination of a seed lot in a laboratory is the emergence and development of the seedling to a stage where the aspect of its essential structures indicates whether or not it is able to develop further in to a satisfactory plant under favorable condition in soil. It is recommended to conduct seeds testing for Hashab before planting in the nursery or in the field.
- ➢ Seed health testing, therefore, is necessary to obtain information regarding health status of a seed lot which is necessary for the seed borne inoculums may give rise to progressive disease development in the field and reduce the commercial value of the crop and transported seed lots may introduce new diseases.
- ➢ It is important to understand the full spectrum of seed handling activities. Poor handling by others at any previous or subsequent stage may negatively impact product.
- ➢ The production of high quality planting stock material should be based on high quality seed source. The application of any new technology of large-scale seedling production it is recommended to certified seeds of high quality and quantity.
- ➢ It is also recommended to be as efficient as possible with tree seeds.
- ➢ Analytical data are presented for the gum exudates from several trees of present or possible future ecological interest within the Republic of the Sudan. There are clear indications that an increasing measure of applied research involving such forestry products should be financed and undertaken within the Sudan.
- ➢ It is recommended to tap trees which have sizable stem and braches

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