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Full Length Research Paper

An evaluation of seedling growth traits and early tapping development of gum arabic (*Acacia senegal* (L) Willd)

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Heritability and expected genetic advance for seedling growths traits in relation to early tapping maturity were studied in six provenance populations of *Acacia senegal* using a 6 × 6 diallel crossing procedure according to Griffing's model 1, method 2. The 15 F_1's and the six parents, namely Karasuwa, Baimeseri, Shagari, Gajiram, Yenegere and Maino were evaluated in two locations, Gashua in Yobe state and Yola in Adamawa state Nigeria. In 2009 dry season, the 21 entries were sown in poly bags and laid out in a Randomized Complete Block Design replicated three times. Seedling growths traits were measured and subjected to diallel analysis and heritabilities in narrow and broad senses as well as genetic advance were estimated by means of variance components for seedling growth traits and possible use for selection in relation to early tapping maturity. Low heritability with moderate genetic advance observed in seedlings height, stem length and canopy spread indicated environmental control on the expression of the traits. Number of primary branches revealed moderate broad and low narrow sense heritabilities which in turn produce low expected genetic advance. Bark thickness and stem diameter expressed high heritability coupled with high genetic advance which indicated that the traits were mainly controlled by additive type of genes and that direct selection for these traits could be effective. The results indicated that bark thickness and stem diameter were heritable and expected genetic advances indicated that improvement in population means can be obtained in crosses for all traits.

Key words: Heritability, genetic advance, gum arabic, tapping maturity.

INTRODUCTION

Acacia senegal (L) Willd is a leguminous multipurpose African tree species belonging to the family *Fabaceae* (Dorthe, 2000). It is a woody species varying in habit from a shrub of about 2 m to a tree of about 15 m high with umbrella-shaped crown (Brenan, 1983). Tapping time has been observed to be governed by age of tree, physiological growth and development. This is when the trees are about 5-7 years old, stem diameter 5 cm and height of 1.2 - 1.5 m depending on management practices

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(Jamal and Huntsinger, 1993). Annual gum yields from young trees may range from 188 to 2856 g, for older trees (7-15 years), 379 to 6754 g (Hines and Eckman, 1993). Gum arabic is the dried exudates obtained from the stems and branches of *A. senegal* (L) Willd (FAO, 1999). Grade one gum arabic is a multifunctional food additive used in confectionery, pharmaceuticals, food and beverages, brewing among others (Leung, 1980). The volume of international trade on gum arabic ranges from 50,000-60,000 tons/annum (ITC, 2009).

In Nigeria production figure for 2002 and 2004 was estimated at 16,071 and 17,206 tons, respectively (RMRDC, 2004). In 2008, the figure dropped to about 12,000 tons from a record as high as 21,767 tons recorded in 2003 (Okoro, 2009). A ton of Nigerian raw gum arabic valued USD 1,500 in 2005, USD 3,000 in 2008 but dropped to USD 1,600 in 2011 due to global economic recession (ITC, 2011).

Heritability can be expressed in the narrow or broad sense. Narrow sense heritability is due to the additive genes effects.

It gives an indication of the predictive component of heritability. Broad sense heritability is based on additive and dominant gene effects (Haynes et al., 1995). Heritability estimates is important for the determination of genetic gain due to selection. The progress due to selection is directly related to heritability (Falconer, 1989). Generally the narrow sense heritability estimates for traits of most forest tree species are low to moderate largely due to dominance, epistatic, and environmental effects (Cornelius, 1994).

The expansion of *A. senegal* production in Nigeria to meet the growing demand for export and local industries will therefore depend on the recognition of traits that are important in selection for early tapping maturity. Thus, the analysis of seedling growths traits is an important technique to establish relative importance of different traits in establishing heritability values (Varghese, 1999). In breeding *A. senegal* for earliness, little information is available regarding the criterion to use for selection of provenances with early tapping maturity. In addition, there has been limited report on the inheritance of early tapping maturity in *A. senegal*. The objectives of this study were to estimate heritability and genetic advance for seedling growth traits that determines early tapping maturity of *A. senegal*.

MATERIALS AND METHODS

Six (6) *A. senegal* provenances (Karasuwa, Baimeseri, Shagari, Gajiram, Yenegere and Maino) were utilized because of their divergent morphological and agronomic characteristics, and used as parents in a half diallel (Parents and F_1's only) at Rubber Research Institute of Nigeria, Gum Arabic Sub - Station Gashua, located at latitude 12° 45'N and Longitude 11° 00'E at an altitude of 360 m above sea level and is located within the Sahel savannah ecological zone in Nigeria. The diallel mating design of method 2 of Griffing (1956) was applied. Hand pollination was carried out using surface sterilized forceps to open up the petals, emasculation of anther of chosen female before natural anthesis followed by cross pollination using pollen from matured male flowers of the male parent to pollinate the receptive stigma of the emasculated flower to generate a 6 × 6 half diallel crossed seeds. In 2009 dry season, the 15 F_1 progenies and the 6 parents were evaluated in a Randomized Complete Block Design (RCBD) replicated three times at Gashua and Yola, respectively. The two locations represented Sahel and Sudan ecological zones that support gum arabic production in Nigeria. The first site was the nursery of Rubber Research Institute of Nigeria Gum Arabic Sub- Station Gashua and the second site was the Landscape Unit nursery of Madibbo Adama University of Technology, Yola located at latitude 9° 14'N, longitude 12° 32'E and altitude of 200 m above sea level. Seeds were sown at a depth of 1 cm and were thinned down to one seedling per poly bag two weeks after emergence. The poly bags were then watered after sowing twice a day except on days with rainfall. All other cultural practices like weed control were observed as recommended by Ojiekpon and Aghughu (1997). Five (5) seedlings were sampled at random for measurement to assess growth data like plant height (cm), number of primary branches, stem length (cm), canopy spread (cm), bark thickness (cm) and stem diameter (cm). The analysis of variance was conducted with estimates of GCA and SCA using the DIALLEL-SAS05 which is a comprehensive program for Griffing's and Gardner-Eberhart analysis (Manjit et al., 2005). The heritabilities of seedlings growth traits were estimated from the formulae given bellow as described by Allard (1960):

$$\text{H (Broad sense)} = \frac{\delta^2 G}{\delta^2 P} = \frac{\delta^2 A + \delta^2 D}{\delta^2 A + \delta^2 D + \delta^2 E}$$

$$\text{H (Narrow sense)} = \frac{\delta^2 A}{\delta^2 P} = \frac{\delta^2 A}{\delta^2 A + \delta^2 D + \delta^2 E}$$

Where

$\delta^2 A$ = Additive genetic variance
$\delta^2 D$ = Dominant genetic variance
$\delta^2 G$ = Genotypic variance
$\delta^2 P$ = Phenotypic variance
$\delta^2 E$ = Environmental variance
H = Heritability

The expected genetic advances for l0 percents selection intensity of plant height, number of primary branches,

Table 1. Heritability for seedlings growth traits calculated from estimated variance component.

Traits	Heritability	
	Broad sense	Narrow sense
Plant height	0.07	0.05
Number of primary branches	0.45	0.20
Stem length at first branching	0.07	0.04
Canopy strength	0.17	0.13
Bark thickness	1.00	0.69
Stem diameter	1.00	0.74

Table 2. Expected genetic advance for each traits at l0% selection intensity (K = 1.75).

Traits	Heritability	
	Broad sense	Narrow sense
Plant height	4.17	3.50
Number of primary branches	2.81	1.88
Stem length at first branching	2.54	1.90
Canopy strength	5.16	4.50
Bark thickness	6.04	5.04
Stem diameter	4.51	3.87

canopy spread, stem length; bark thickness and stem diameter were estimated from the formula given below as described by Allard (1960):

$$G = K\sqrt{\delta_P^{\,2}\,.H}$$

Where K = selection differentials (1.75).

RESULTS AND DISCUSSION

The means of the heritability estimates viz., broad sense and narrow sense for plant height (0.07 and 0.05), stem length (0.07 and 0.04), and canopy spread (0.17 and 0.13) were observed (Table 1). The expected genetic advance in broad and narrow sense for plant height (4.17 and 3.50%), stem length (2.54 and 1.90%) and canopy spread (5.16 and 4.50%) was observed at a selection intensity of 10% (Table 2).

Low heritability with moderate genetic advance observed in seedling height, stem length and canopy spread indicates environmental control on the expression of the traits (Goodger et al., 2004). This result is similar with the findings of Cornelius (1994) who observed that narrow sense heritability estimates for traits of most forest tree species are low to moderate largely due to dominance, epistatic, and environmental effects. According to Robinson et al. (1949), heritability mean of 0-0.3 is low, 0.4-0.6 moderate, and 0.6 and above high.

In this study, heritability estimates for number of primary branches were moderate in the broad (0.45) and low in narrow (0.20) sense, which produce expected genetic advance of 2.81 and 1.88% respectively. According to Johnson et al. (1955) effectiveness of selection depends not only on heritability but also on genetic advance. Thus moderate heritability coupled with low genetic advance observed for number of primary branches indicating that the trait is mainly controlled by non-additive genes (dominance and epistasis). The highest heritability estimate in the broad and narrow sense were recorded for bark thickness (1.00 and 0.69) and stem diameter (1.00 and 0.74) respectively, which also gave expected genetic advance of (6.04 and 5.04%), (4.51 and 3.87%) respectively. Hence, high heritability coupled with high genetic advance observed for bark thickness and stem diameter indicates that the traits are mainly controlled by additive genes and that direct selection for these traits could be effective.

Conclusion

The narrow and broad sense heritability and expected genetic advance for bark thickness and stem diameter were observed. The heritability estimates indicate that the two traits were heritable and slightly affected by the environmental factors. The evaluation for genetic advance indicates that improvement in population means can be obtained in crosses for all traits.

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