



PERFORMANCE OF 28-YEAR-OLD PROVENANCES OF LIQUIDAMBAR STYRACIFLUA AT TWO SITES IN WESTERN KENYA

Joram M. E. Mbinga^a and Ebby Chagala-Odera^b

a. Kenya Forestry Research Institute, Rift Valley Eco-Region Research Programme-Londiani P.O. Box 382-20203, Londiani. Kenya.

b. Kenya Forestry Research Institute, Headquarters, Nairobi, P.O. Box 20412-00200, Nairobi, Kenya

*Corresponding author's Email: jmbinga@gmail.com

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Abstract: The phenotypic variation in growth of ten 28-year-old *Liquidambar styraciflua* provenances was studied at two sites, Lugari and Kakamega in Western Kenya. The trial at each site was established in a Randomized Block Design with the ten provenances replicated in four blocks. Each block had ten square plots corresponding to the ten provenances and each plot had thirty six trees. Analysis of growth data gave results which showed a significant difference ($P < 0.01$) in survival, and growth parameters of tree height, and diameter at breast height (Dbh) among provenances at both sites. Ranking based on height growth of the provenances showed the best provenance at Lugari site was Finca Las Victoria-Guatemala, with mean height and Dbh of 35.8 m and 37.1 cm respectively, while the leading provenance at Kakamega site was Tactic Coban, Guatemala, with a mean height and Dbh of 28.7 m and 26.8 cm respectively. The provenance with highest mean survival at Lugari was Finca Las Victoria-Guatemala with a value of 29.2%, while at Kakamega the best provenance was Franklin, Virginia-USA, with a value of 72.2%. Provenance by site interaction was significant as shown by the difference in performance of provenances between the sites. A comparison of the result from the best performing provenances with the growth of the most commonly grown *Cupressus lusitanica* species in similar sites in Kenya indicates the high potential of *L. styraciflua* as a commercial plantation species in medium altitude sites in Kenya.

Keywords: *Liquidambar styraciflua*, Provenances, Survival, Trial, Performance.

Postal Address: Kenya Forestry Research Institute, Rift Valley Eco-Region Research Programme-Londiani P.O. Box 382-20203, Londiani. Kenya. Tel +254-722305858

INTRODUCTION

One of the strategies that various countries use for maintaining successful commercial forest plantations programs is the use of a wide range of species with desirable characteristics. This ensures a sustainable supply of forest products in the face of possible fluctuations in market preferences and is also security in the event of emergence of previously unknown pests, diseases and other disasters that often result in great losses (Diro, 2006). This strategy has found relevance in Kenya where in several instances; planting of one species has been reduced or discontinued due to pests and

diseases. In the past, the plantation species *Cupressus macrocarpa* was attacked by *Monochaeta* canker in 1965 (Odera, 1990) and was replaced by the more fungal resistant *Cupressus lusitanica*. Also, when *Pinus radiata* was attacked by *Dothistroma pinii* in 1969 (Forest Department, 1969), it was replaced by planting the more disease tolerant *Pinus patula* species. Preparedness for this kind of eventuality calls for carrying out trials of new exotic species and provenances with potential for large scale plantation establishment and testing them in matching sites. It was against this background that the tree species

Liquidambar styraciflua was introduced in Kenya to test its growth performance.

L. styraciflua is a fast growing hardwood tree species of North and Central America and is considered very promising for the American tropics (McCarter and Hughes, 1986). The species occurs naturally between the latitudes 13°N to 41°N. It is frequently found at altitudes between 900 and 1,600 m.a.s.l., rainfall of between 1500-1800 mm per annum and temperatures of 13°C to 21°C. It prefers deep clay loam acidic soils, though it adapts most easily to different soils and site conditions (McCarter and Hughes, 1986). The tree grows moderately fast, is highly resistant to insect attack (Jetton and Robison, 2014) and has a very straight trunk, light branching and narrow crown. This medium to large deciduous monoecious tree is capable of reaching heights of 45m and Dbh of 60cm at maturity in 40 years (Kormanik 1990). It is a multipurpose tree whose wood can be used for sawn timber for general construction and furniture, pulp, firewood and is of special value in veneer and plywood industries (Durkovic and Lux, 2010). Chemists have found that the seeds of *L. styraciflua* fruit contain significant amounts of shikimic acid, the starting material used to produce the main antiviral agent in a much-heralded lifesaving drug against bird flu (Coutant Debbie, 2006), which is in short supply worldwide. The species is therefore of international importance since it has the potential of providing a solution to a worldwide problem. Also, the essential oils produced by the species are used to treat inflammation (El-Readi *et al.*, 2013). Due to its wide natural distribution, the phenology and growth traits of *L. styraciflua* vary significantly among different seed sources (Gurgel-Gorrido *et al.* 1997) The species has been successfully introduced in Brazil and other tropical countries where it has adapted to growing outside its natural sites where the fastest growing provenances have attained productivity of 40 m³ ha⁻¹ year⁻¹ (Gurgel-Gorrido *et al.* 1997; Sebbenn *et al.* 2007). In Kenya, the growth performance of ten *L. styraciflua* provenances was assessed 28 years after planting at two sites. The objectives of the trials were to study the phenotypic

variation in main silvicultural traits among the provenances, determine survival of different provenances and classify the provenances by ranking them according to their silvicultural performance.

EXPERIMENTAL

Plant material: Seeds for the trial were collected from trees from the ten *L. Styraciflua* provenances in Mexico USA and Central America by the Commonwealth Forestry Institute, UK (McCarter and Hughes, 1986). The geographic and climatic characteristics of sites where the ten seed lots were sourced are shown in Table 1.

Trial Sites: The trials were established in 1986 at two sites, namely Lugari and Kakamega both of which are in Western Kenya. Lugari is at an altitude of 1600 m.a.s.l., latitude 0° 38'N and longitude 35° 41'E. The mean annual rainfall and temperature is 1450 mm and 20°C respectively. The soils are dark red loams. The Kakamega site is at altitude of 1650 m above sea level, latitude is 0° 17'N and longitude is 35° 06'E. Mean annual rainfall and temperature are 1750 mm and 18°C respectively. The soils are deep acidic loamy clay with pH 4-5 (Jaetzold and Schmidt, 1982).

Experimental layout and data analysis: At each site, trials were established in a Randomized Block Design with the ten provenances, replicated in four blocks. Each square plot in a block had thirty six trees at a spacing of 2.5 x 2.5 m. The trial was maintained, monitored and measurements of height, diameter at breast height (Dbh) and survival done periodically after one, three, seventeen, and twenty eight years of planting. The latest analyses of variance (ANOVA) for growth parameters of height and diameter at twenty eight years were done using Genstat 16th Edition statistical computer software.

RESULTS AND DISCUSSION

Growth in height and diameter at breast height (Dbh): Height, Dbh and ranking based on height growth of provenances (Table 2 and Table 3) showed that the leading provenance at Lugari was Finca Las Victoria–Guatemala, with mean height and Dbh of 35.8 m and 37.1 cm

respectively, while the leading provenance at Kakamega was Tactic Coban-Guatemala, with a mean height and Dbh of 28.7 m and 26.8 cm respectively. Analysis of variance (ANOVA), in height and Dbh growth showed a significant difference ($p < 0.001$) in those traits among the provenances at both sites. Franklin-Virginia, USA provenance did not survive at Lugari site.

Provenance by site interaction: The analysis of provenance by site interaction (Table 4) shows a significance difference in both height and Dbh growth among the provenances at the two sites.

Survival: The provenance with highest mean survival Figure 1, at Kakamega was Franklin, Virginia-USA, with a value of 72.2%, while at Lugari it was Finca Las Victoria - Guatemala with a value of 29.2%.

The ten provenances tested in this study are reported (McCarter and Hughes, 1986), to have a wide genetic base covering most of the natural range of the species from USA, through Mexico, to South America. This is reflected in the results, which showed significant differences in performance among the provenances. In a similar study conducted in North Carolina USA on *L. styraciflua* Mexican and USA populations, Hoey and Parks (1994), found genetic variation to be partitioned within populations and genetic identity among populations to be high. This indicates that high genetic gains could be obtained from a breeding programme that takes advantage of variations among different populations of the species. Growth performance of the best provenance of *L. styraciflua* at the better site in Kenya (35.8m height and 37.1 cm Dbh), was

much higher than what had been reported in similar trials in other countries. For instance in Mississippi USA, Krinard and Johnson (1985), reported best height and Dbh of 20 m and height of 26 cm in a trial at 18 years. While Sebbenn *et al.* (2007) reported the best performing *L. styraciflua* provenances achieving 18.3m height and 21.5cm Dbh in Brazil at age of 19 years. Results that were very close to those obtained in this study were also reported by Rakotovololonimanana *et al.* (2014) in Madagascar. They obtained a mean height of 26 m and Dbh of 38 cm from the best *L. styraciflua* provenance at 25 years in a similar study using planting material collected by the Commonwealth Forestry Institute. It is interesting to note that the best performing provenance at Lugari site, Finca Las Victoria-Guatemala, was also reported to be the best provenance in two different trials at different times in Brazil (Gurgel-Gorrido *et al.* 1997, Sebbenn *et al.* 2007). However, early growth (1-5 years), of this provenance was reported not to be outstanding in the trials in Kenya (Kariuki, 1989). Compared to *Cupressus lusitanica*, the most widely planted commercial species in Kenya, *L. styraciflua* gives better performance on comparable sites. In a comparative progeny trial in Kenya of various seed sources, Kariuki and Chagala (1996) reported average height and Dbh for local commercial seeds of *C. lusitanica* at age 20 years to be 18.9m and 28.0cm respectively, while Kigomo (1990), found lower growth figures for *C. lusitanica* from a thinning trial at Elburgon, Kenya.

Table 1. Seed origin of *Liquidambar styraciflua* planted in the trials at Lugari and Kakamega, Kenya

Local No.	CFI* Seed lot No.	Provenance	Particulars of Provenances			
			Latitude N	Longitude W	Altitude (m)	Rainfall (mm)
1	5/84	Finca Las Victoria-Guatemala	15°12'	89°22'	900	1750
2	2/85	Franklin - Virginia, USA	36°41'	76°58'	30	1175
3	1/85	Huntsville-TexasUSA	30°43'	95°34'	132	1175
4	47/83	Las Lajas - Honduras	14°48'	87°34'	1150	1750
5	81/83	Tutule Lapaz - Honduras	14°12'	87°50'	1550	1650
6	45/83	Montebello-Chiapas, Mexico	16°04'	91°50'	1500	2000
7	6/84	Tactic Coban-Guatemala	15°19'	90°21'	1400	2075
8	48/83	Yucul Matagalpa-Nicaragua	12°55'	85°48'	1500	1500
9	46/83	Los Alpes - Honduras	14°33'	87°58'	1300	1500
10	82/83	Huatusco Veracruz-Mexico	19°05'	97°00'	1450	1746

*CFI; Commonwealth Forestry Institute.

Table 2. Ranking of *L. styraciflua* provenances based on 28-year height growth at Lugari, Kenya

Rank	Mean Ht (m)	Mean Dbh (cm)	Provenance
1	35.8 a	37.1	Finca Las Victoria – Guatemala
2	34.8 a	31.6	Los Alpes – Honduras
3	34.0a	32.0	Yucul Matagalpa – Nicaragua
4	32.4 ab	27.6	Montebello – Chiapas, Mexico
5	32.2 ab	31.4	Las Lajas – Honduras
6	24.6 ab	28.2	Tactic Coban – Guatemala
7	25.5 bc	26.2	Tutule Lapaz – Honduras
8	19.1 c	21.2	Huatusco Veracruz – Mexico
9	8.6 d	14.7	Huntsville – Texas, USA
10	0	0	Franklin – Virginia, USA
Mean	21.1	25	-

Note: Means followed by the same letter are not significantly different.

Table 3. Ranking of *L. styraciflua* provenances based on 28-year height growth at Kakamega, Kenya

Rank	Mean Ht (m)	Mean Dbh (cm)	Provenance
1	28.7 a	26.8	Tactic Coban – Guatemala
2	21.8 b	17.4	Huatusco Veracruz – Mexico
3	20.8 b	20.0	Los Alpes – Honduras
4	20.3 b	17.9	Franklin – Virginia, USA
5	20.2 b	17.3	Montebello – Chiapas, Mexico
6	19.7 b	19.9	Tutule Lapaz – Honduras
7	19.5 b	17.3	Yucul Matagalpa – Nicaragua
8	19.5 b	19.9	Las Lajas – Honduras
9	17.6 b	15.7	Finca Las Victoria – Guatemala
10	17.4 b	16.8	Huntsville – Texas, USA
Mean	20.6	18.9	-

Note: Means followed by the same letter are not significantly different.

Table 4. Analysis of Provenance x Site interaction

Source of variation	d.f.	DBH		Height	
		MS	F	MS	F
Site	1	23882.7	710.3**	17603.8	659.4**
Provenance	9	1155.8	34.4**	1728.0	64.7**
Site x Provenance	8	1577.5	46.9**	1953.3	73.2**
Residual	897	33.6		26.7	

Note: ** Denotes significance at 0.01 probability level.

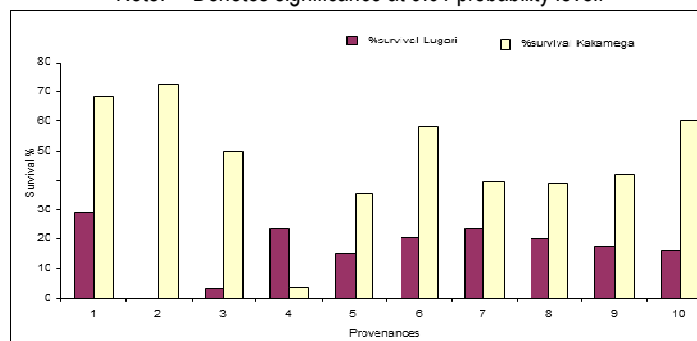


Figure 1. Survival of *L. styraciflua* provenances at Lugari and Kakamega after 28 years of growth

Legend: Provenances; 1. Finca Las Victoria-Guatemala, 2. Franklin-Virginia, USA, 3. Huntsville-Texas, USA, 4. Las Lajas-Honduras, 5. Tutule Lapaz-Honduras, 6. Montebello-Chiapas, Mexico, 7. Tactic Coban-Guatemala, 8. Yucul Matagalpa-Nicaragua, 9. Los Alpes-Honduras, 10. Huatusco Veracruz-Mexico.

Other workers (Albayrak and Arican, 2009), evaluated different *Liquidambar* sp. genetic

material using Random Amplified Polymorphic DNA (RAPD) and other molecular markers whereas this study relied only on

morphogenetic traits to evaluate performance of different genetic material. The limitation in the later method is lack of certainty in the correct identity of the material being used.

A comparison of site by site performance shows that mean height and Dbh of the provenances was higher at Lugari compared to Kakamega site. This is probably due to high rainfall (1750 mm) at Kakamega, which was beyond the optimum for the species as reported by McCarter and Hughes (1986). However, this again differs from preliminary results reported after five years, where growth at Kakamega was better compared to Lugari (Kariuki, 1989). This could be explained by variation among provenances in adaptation to growing conditions over time, and confirms the unreliability of using results at an early age to determine adaptability. On the basis of survival, Kakamega site gave better results than Lugari, probably because the species was favored by the deep acidic loamy clay soil in Kakamega which was reported to be optimum for the species (McCarter and Hughes 1986). Elsewhere, Krinard and Johnson (1985), also reported differences in growth performance in *L. styraciflua* on two sites in Mississippi and attributed this to differences in soil conditions. At provenance and site level, most provenances showed high site specificity. For example, Finca Las Victoria-Guatemala provenance was the best in growth at Lugari but was among the poorest in Kakamega. Similarly, the best provenance in Kakamega (Tactic Coban) is ranked seventh in Lugari. The most striking was Franklin, which had the best survival and impressive growth in Kakamega, but did not survive in Lugari. The results suggest that Finca Las Victoria-Guatemala provenance was the most adaptable and recommended for growing in Lugari area, while Tactic Coban-Guatemala can be recommended for Kakamega site.

CONCLUSION

The findings from this study indicate that selected *L. styraciflua* provenances have potential for growth in selected sites in Kenya. It therefore requires careful provenance and site matching to achieve best results. An

expanded programme of demonstration plots establishment using suitable provenances in selected sites is therefore recommended as a way of putting the results of this study into use.

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