TRIALS AND GROWTH OF PINUS CARIBAEA IN NORTHERN NIGERIA

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Abstract

From the trial plantings of exotic tree species which commenced in the Northern areas of Nigeria over 20 years ago, apart from some species of eucalypts which have been earmarked as promising and now feature prominently in afforestation programmes in these areas, *Pinus caribaea* variety *hondurensis* (out of all the varieties of the species tried) has been identified as the next most promising and widely planted species within the low and medium altitude areas (600–1200 m) of that part of the country.

Growth data from permanent sample plots from the Northern parts of the country showed that, on an average site, *P. caribaea* var. *hondurensis* attained a top height of 23.4m at a reference age of 20 years and that a maximum mean annual increment (M.A.I) of 24.2m^3/ha/yr could be obtained at age 30 with an overbark total volume production of about 726m^3/ha. Among the other things discussed are the factors influencing the growth rate of the species and the application of the resulting growth figures to its management.

Introduction

Keay (1959) broadly classified the vegetation of Nigeria into two major regions, viz: the savanna region and the forest zone. The savanna region covers the northern four-fifths of the country (about 800,000 Km^2) and is subdivided into Southern Guinea, Northern Guinea, Sudan and Sahel savanna zones including a transitional rain-forest/savanna termed the "derived savanna" (Fig. 1). The slow growth rates of the indigenous tree species in most of the savanna areas (Kemp, 1963) coupled with forest devastation activities as caused by farming, over-grazing, over-exploitation of the forests for wood, bush-fires etc have rendered the indigenous forests incapable of meeting, both in quantity and quality, the rapidly increasing wood requirements for sawnwood, fuelwood, telephone and transmission poles. In order to meet these wood requirements and also to reduce the effects of desertification in the further north of the

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country, intensive trials of exotic tree species including some of their provenance testings commenced in the savanna region of Nigeria around 1959 (Kemp, 1969).

The encouraging results from the series of selection work that followed the trial plantings (Kemp, 1970. Iyamabo *et al*, 1972; Anon, 1974) led to the establishment of large scale plantations of some of the promising species, mostly eucalypts and pines. A preliminary survey of the growth of eucalypts tried in the Northern areas of Nigeria has been discussed (Adegbehin, 1983). From a preliminary evaluation of performance of pines tried, *Pinus oocarpa* and *P. caribaea* have been known as the most promising species within the low and medium altitude areas (600–1,200m) of Northern Nigeria while *P. patula, P. radiata* and *P. khasya* are more adapted to the Mambilla Plateau, the high altitude areas (1,500–1,850m) as earlier reported (adegbehin *et al*, 1985). Although *P. oocarpa* seems to have a slightly faster growth than *P. caribaea* in the areas covered (Adegbehin, 1980; Otegbeye, 1985), it is the latter that has been discussed in this paper as its plantations are older and greater than those of *P. oocarpa*. This review is focussed, among other things, on the areas suitable for the planting of the species in Northern Nigeria, the provenances and the varieties of the species tried and the variety commonly raised in plantations, its growth rate and anticipated rotation age.

Areas suitable for planting of *P. caribaea* in Northern Nigeria

The areas suitable for the planting of *P. caribaea* as well as *P. oocarpa* in the Northern parts of Nigeria at present lie within the Northern Guinea savanna zone (the Jos Plateau and its neighbouring lowland derived savanna areas, Nimbia and Kafanchan, inclusive, (Fig. 1). Some plantations of the species have been established at Afaka and Nimbia (Kaduna State) and Miango, Vom and Ta-Hoss (Plateau State). The site characteristics of these locations vary to some extent (Table 1).

As at the end of 1985, Kaduna State had the largest area of *P. caribaea* plantations as compared to the other Northern States (Plateau, Bauchi, Kano, Sokoto, Benue, Borno, Niger, Gongola and Kwara States, (Fig. 1). The area of *P. caribaea* established up to 1985 in this State accounted for about 250 ha out of a total area of about 300 ha of pines raised and there appears to be brighter hope that this species will continue to be raised in larger proportion probably due to its higher fire-resistant ability compared with the other species of pines.

The Southern Guinea zone (around Mokwa and along the Niger valley), the Sudan zone (around Kano) and the Sahel zone (around Lake Chad) are too hot and it has not been possible to find a suitable pine mycorrhizal fungus that can withstand high soil temperature. All efforts directed towards the establishment of pines around Mokwa (within Niger State) have met with little or no success due to poor survival of the mychorrizal fungus, *Rhizopogon luteolus*, at high temperature (Momoh, 1973). The introduction of another mychorrizal fungus, *Pisolithus tinctoris*, which is believed to resist high soil temperature had only succeeded in increasing the survival of pines at Ejidogari, South-west of Mokwa, to 40% at establishment (Adegbehin *et al*, 1985). However, in the Southern parts of Nigeria, principally in the Cross River, Imo and Anambra States, larger plantations of pines (mostly *P. caribaea* and *P. oocarpa*) have been established but growth figures of the species from these areas are lacking.

Provenance Selection

Provenance trials of *P. caribaea* as well as those of *P. oocarpa* and *P. khasya* commenced in earnest in the savanna region of the country in 1968 (Ojo and Shado, 1973) although it appears that some promising provenances had actually been raised in plantations before this time. Out of the three varieties of *P. caribaea* tried in the savanna region of Nigeria, viz: *P. caribaea* var. *caribaea* (from Western Cuba and Isles of Pines), *P. caribaea* var. *bahamensis* (from Bahamas Island, Great Abaco, Andros, New Providence and Caicos) and *P. caribaea* var. *hondurensis* (from Belize, Guatemala, Honduras and Nicaragua), *P. caribaea* var. *hondurensis* has been found to be preferred to the other varieties and those from Belize and Guatemala were tentatively the best seed sources (Ojo and Shado, 1973). The criteria used to arrive at this conclusion at that early stage (age of 5 years) were survival and height growth. Otagbeye and Shado (1984) using the criteria of height and diameter growth at age 12 arrived at a more concrete conclusion that *P. caribaea* var. *hondurensis* from Nicaragua, Mt. Pine Ridge (Belize) and Guatemala performed best in each of the three test locations comprising of Afaka, Nimbia and Miango in the Northern parts of Nigeria (Fig. 1). In an earlier report in which the height growth data of the provenances were compared at age 12, Otegbeye (1980) found that *P. caribaea* var. *caribaea* came second while all the members of the var. *bahamensis* fell into the third or last category. He further noted that the height growth data for the three varieties of *P. caribaea* examined were superior at Miango which is at a higher altitude (1,300 m) as compared with those from Afaka and Nimbia lying within the altitude range of 600–640 m.

In a proposal for the genetic improvement of *P. caribaea* var. *hondurensis* in the savanna region of the Nigeria, Otegbeye (1986) concluded that, since the provenances of this variety so far tried in that part of the country exhibit fairly similar growth rate and form characteristics, their seeds could be bulked together for the establishment of industrial plantations and that breeding materials of superior quality (seeds or vegetative parts) could then be selected across the provenances. At present, most of the plantation of *P. caribaea* var. *hondurensis* existing in the Northern parts of the country are established from seeds from Mt. Pine Ridge, Belize, where the seeds are readily available.

Spacing Trial

An appropriate stand density must be maintained in order to optimise the total volume production for use by the wood-based industries. The spacing trial of *P. caribaea* var. *hondurensis* set up at Afaka (Kaduna State) in 1968 was the first in Nigeria to monitor the effects of espacement on the growth of the species. The espacements adopted in the trial varied from 2.3 m by 1.2 m to 3.4 m by 3.4 m (density range of about 860 to 3,600 stems/ha) and it was based on the Latin square design with four treatments and four replications. Results of the first assesment at age 5 showed that there was no advantage in adopting spacings wider than 2.7 m by 2.7 m and at a stocking less than 1,270 stems/ha competition had not yet set in (Anon, 1974).

Results of the second assessment at age 10 revealed that while the stand mean diameter, basal area (m^2/ha) and total volume production were significantly affected by spacing; top

height, mean height, mean diameter of dominant trees and form factor (overbark) were not (Shado and Adegbehin, 1985). Regression analyses showed that the stand parameters significantly affected by spacing could be reliably predicted from stand density within the range of field data. It was further noted that, at age 10, a maximum total volume production (overbark to 7.5 cm diameter top) of about 240 m^3/ha with a stand mean diameter of about 11.9 cm was obtained at a stocking of about 3,300 stems/ha. It was however found that the point which compromised tree size with the total volume production was a density of about 2,500 stems/ha with a mean diameter of about 12.7 cm and a volume production of 192 m^3/ha. So far, the commonly adopted espacement for this species as well as the other exotic tree species grown in the Northern parts of Nigeria has been 2.7 m by 2.7 m.

Growth Rate

As *P. caribaea* var. *hondurensis* is the most promising of all the three varieties tested and also the most widely planted in Northern Nigeria, all efforts have been directed to the study of its growth rate. At one of the plantation areas, Afaka, where various exotic tree species are represented, it has been found that, in general, *P. caribaea* has a slightly lower growth rate than *P. oocarpa*. Moreover, the eucalypts, particularly *Eucalyptus camaldulensis* (Petford provenance) and *E. cloeziana*, which however, is not reliable on all soil types, are faster-growing than *P. caribaea* (Table 2). However, with increasing age (as from the age of about 16 years), *P. caribaea* has a faster growth and hence a higher total volume production than the species of eucalypts mentioned (Adegbehin *et al*, 1986). This of course implies that *P. caribaea* is naturally a longer rotation species than the eucalypts.

From more detailed studies based on growth data from 53 permanent sample plots at ages 4–29 years from the plantation areas comprising of Afaka, Nimbia, Miango, Vom and Ta-Hoss, provisional site classes were distinguished at a reference age of 20 years (Adgbehin, 1985); site class I (26.4 m at age 20); II (23.4 m) and III (20.4 m). The three provisional site classes were found to compare favourably well with the three "height classes" (site classes) constructed for the species at Trinidad and Tobago by Lackhan (1972), see Table 3.

Based on the three provisional site classes constructed, classifying the two plots that were at least 20 years old, only the stand established at Miango (on the Jos Plateau) in 1961 falls in site class I (attaining a top height of 25.6 m at age 20) while the plot at Vom (also on the Jos Plateau) planted in 1954 falls in site class II (the average site, with a top height of 23.4 m at age 20). Though most of the other plots are still young, majority of those at Nimbia (derived savanna vegetation type) are likely to fall within site classes I and II while most of those at Afaka (typical Northern Guinea savanna) may be within site classes II and III.

In a study of the total volume production (TVP) figures for the average site (site class II), it was found that the current annual increment (C.A.I.) reaches its peak of 35.5 m^3/ha/yr at the age of about 20 years with a TVP of about 415 m^3/ha (Table 4). Similarly, the mean annual increment (M.A.I.) is anticipated to attain its maximum value of 24.2 m^3/ha/yr at the age of 30 with a TVP of about 726 m^3/ha. Although these figures may be regarded as tentative

since the point of culmination of the M.A.I., in particular, lies outside the range of field data, they compare very well with what have been obtained elsewhere. The yield figure of 726 m^3/ha (volume overbark to 7.5 cm diameter top) obtained for the average site at age 30 (M.A.I. = 24.2 m^3/ha/yr) cannot be said to be too low compared with the yield of 644 m^3/ha (volume underbark to 7.5 cm diameter top) obtained at age 29 (M.A.I. = 22.2 m^3/ha/yr) for a good site for the same species at Zululand, South Africa (Lamb, 1973).

With regard to the age at which the M.A.I. reaches its peak, Lackhan (1972) indicated that this varies to some extent; he cited an age range of 25 – 30 years for *P. caribaea* grown in Trinidad, depending on site quality, while Luckhoff (1964) stated that the M.A.I, reached its peak at the age of 33 in Zululand. Therefore, the results so far obtained in Northern Nigeria lie within the range expressed by these authors.

Among the most important factors determining the site quality of *P. caribaea* and hence its growth rate are rainfall and soil depth (Adegbehin, 1985). Various studies have shown that soil depth generally limits the rooting zone of the species (Lamb, 1973). However, the growth rate of the species in Northern Nigeria was found to be more correlated with total rainfall than soil depth (Adegbehin, *loc. cit.*). Furthermore, the number of rainy days (per year), which gives an indication of the rainfall distribution, is more important for tree growth than the total rainfall. Hence the growth rate of the species was more correlated with the number of rainy days than the total rainfall. Lamb (*loc. cit.*) has emphasised the impact of rainfall and soil depth on the growth of *P. caribaea* in many countries. He cited a total volume production of about 644 m^3/ha (volume overbark to 7.5 cm diameter top) at age 29 in Zululand with an annual rainfall of about 1200 mm and a good rooting depth as compared with 582 m^3/ha for the same age in Trinidad where these site characteristics were less favourable.

Rotation Age

The rotation age of a tree species depends on many factors such as the uses of the trees (e.g. for poles, sawnwood, pulp and paper), site quality aspects, economic considerations etc. The maximum mean annual increment (M.M.A.I.) plays an important role when deciding on the rotation age of a species especially when meant for sawnwood production in which case larger tree sizes are normally preferred. After the M.M.A.I. has been reached, it becomes unprofitable to continue to retain the stand after a certain age. As the M.A.I is anticipated to reach its peak at the age of 30 on an average site, a rotation age of about 34 years has been suggested on the assumption that the species would be used mainly for sawnwood production. Based on projections outside Table 5 which shows a thinning regime recommended mainly for sawnwood production on an average site, it is envisaged that a standing crop of about 480 trees/ha could be retained up to the suggested rotation age with an anticipated standing volume (overbark) of about 640 m^3/ha, volume/tree of about 1.33 m^3 and a mean d.b.h. of about 34 cm. A rotation age of about 34 years suggested seems to be ideal for the average site. Although Lamb (1973) reported a rotation age of 23–32 years for *P. caribaea* plantations located at Drasa and Seaqaqa in Fiji, the fact that Luckhoff (1964) reported that the M.M.A.I. was attained around 33 years at Zululand implies that a rotation higher than 32 years could still be ideal in some areas.

Conclusions

Out of the three varieties of *P. caribaea* tried in the savanna region of Nigeria, the variety *hondurensis* with seed sources from Mt. Pine Ridge (Belize), Nicaragua and Gutemala has been the most promising and most widely raised in plantations. As a result of high soil temperature inhibiting the development of pine mychorrizal fungus coupled with low rainfall in some Northern areas of the country, establishment of *P. caribaea* plantations has been restricted to the Northern Guinea savanna zone and the derived savanna areas.

The provisional site index and volume figures obtained for *P. caribaea* var. *hondurensis* in the Northern parts of the country have served as a useful landmark in providing tentative growth and yield data for the species. As more data are available from the existing and new sample lots, an improvement will be made to provide additional and perhaps better estimates of growth data for the species. It is also hoped that this investigation will be extended to the other promising provenances and other species.

Table 1. Site characteristics of study areas.

	STUDY AREAS				
			JOS PLATEAU		
	Afaka	Nimbia	Miango	Vom	Ta-Hess
Location	Latitude 10° 37′N Longitude 7° 31′E	Latitude 9° 30′N Longitude 8° 34′E	Latitude 9° 51′N Longitude 8° 52′E	Latitude 9° 43′N Longitude 8° 47′E	Latitude 9° 38′N Longitude 8° 44′E
Altitude (m)	600	640	1300	1250	1250
Mean annual rainfall (mm)	1290	1750	1570	1370	1348
Rainy days/year	180	220	180	190	185
Mean maximum temperature (Hottest months)	35°C (April, May)	36°C (March)	31°C (March)	31°C (March)	31°C (March)
Mean minimum temperature (Coldest months)	14°C (December)	15°C (December)	13°C (December, January)	13°C (December, January)	13°C (December, January)
Mean annual temperature	25°C	26°C	22°C	22°C	22°C
Soil types	Ferrugineous reddish brown tropical sandy clay loam, over plinthite layer pH range: 5.3 – 6.2	Eutrophic dark brown soil, loam to clay loam derived from basalt. pH: 6.0–6.8	Eutrophic reddish brown soil, derived from basalt, mainly clay loam. pH: 5.2–5.6	Eutrophic reddish brown soil, derived from basalt, mainly clay loam. pH: 5.2–5.6	Eutrophic reddish brown soil, derived from basalt, mainly clay loam. pH: 5.2–5.8

Table 2. Data of growth and yields of some exotic tree species at Afaka (Northern Guinea zone)

Species	Age (yrs)	Standing stems/ha.	Top height (m)	Mean height (m)	Total Basal area (m^2/ha.)*	Total volume production (m^3/ha.)*	M.A.I. (m^3ha/yr)	Number of plots
Eucalyptus camaldulensis								
(Petford provenance)	6	1140	19.7	18.2	17.2	113.2	18.9	4/
E. cloeziana	7	912	19.8	18.0	16.6	98.3	14.0	2/
	9	831	22.3	20.1	20.8	153.7	17.1	1/
	13	571	27.8	26.4	27.4	240.6	18.5	2/
Pinus oocarpa	9	1121	16.0	14.5	23.4	152.8	17.0	2/
	9	1080	14.1	12.8	21.8	140.4	15.6	2/
	9	1045	15.0	13.5	23.4	153.0	17.0	2/
P. caribaea								
var. *hondurensis*	9	1190	13.4	12.4	25.4	130.0	14.4	2/
	9	1198	13.2	12.0	24.7	128.0	14.2	2
	9	1135	12.0	11.4	24.0	135.2	15.0	2/

* All basal and volume figures were overbark while the total volume production was calculated up to 7.5 cm diameter top limit.
Source: Adegbehin (1980)

Table 3. Provisional site classes for *P. caribaea* and their comparisons with those of Trinidad and Tobago

Site/Height class**	Provisional site classes		Mid-point for "height classes" for Trinidad and Tobago*
	Class interval (m)	Mid-point (m)	
I	24.9 < 27.9	26.4	25.9
II	21.9 < 24.9	23.4	22.9
III	18.9 < 21.9	20.4	19.8

* The three "height classes" (site classes) for *P. caribaea* were constructed for Trinidad and Tobage by Lackhan (1972)

** Site index reference age for both sets of site classes is 20 years

Table 4. Predicted yield figures for *P. caribaea* on an average site (site index 23.4 m age 20 years)

	Age (yrs)	Top height (m)	Total volume production* (m^3/ha.)	M.A.I. (m^3/ha/yr.)	C.A.I. (m^3/ha/yr.)
	4	6.8	19.3	4.8	
	6	9.0	37.5	6.2	9.1
	8	11.4	65.3	8.2	13.9
	10	13.7	103.7	10.4	19.2
	12	16.0	152.6	12.7	24.4
	14	18.1	210.5	15.0	29.0
	16	20.1	275.3	17.2	32.4
	18	21.8	344.3	19.1	34.5
	20	23.4	414.9	20.7	35.5
	22	24.8	484.8	22.0	35.5
	24	26.0	551.9	23.0	35.0
	26	27.0	615.0	23.6	31.6
	28	27.9	673.0	24.0	29.0
By	30	28.6	725.6	24.2	26.3
Extrapolation	32	29.2	772.5	24.1	23.4
	34	29.7	814.0	23.9	20.8

* Volume production overbark up to 7.5 cm diameter top.
Source: Adegbehin (1985)

Table 5. Estimated yield figures for *P. caribaea* on an average site (site index 23.4 m at a reference age of 20 years) based on a recommended thinning regime

	STANDING CROP						THINNINGS					TOTAL PRODUCTION*	
Age (yrs)	Top Ht. (m)	Stems per ha.	Volume (m^3/ha)	Volume/ tree (m^3)	Basal area (m^2/ha)	Mean d.b.h (cm)	Stems per ha.	Volume (m^3/ha)	Volume/ tree (m^3)	Basal area (m^2/ha)	Mean d.b.h (cm)	Basal area (m^2/ha)	Volume (m^3/ha)
6	9.0	1200	–	–	–	–	–	–	–	–	–	–	–
14	18.1	740	176.5	0.238	27.4	21.7	460	34.0	0.074	4.6	11.3	32.0	210.5
22	24.8	590	390.8	0.662	39.1	29.0	150	60.0	0.400	7.6	25.5	51.3	484.8
30	28.6	480	551.6	1.149	39.9	32.4	140	80.0	0.572	8.2	27.2	60.3	725.6

* All production figures were overbark and volume figures were considered to 7.5 cm diameter top limit, anticipated rotation age being about 34 years.

Source: Adegbehin et al. (1986).

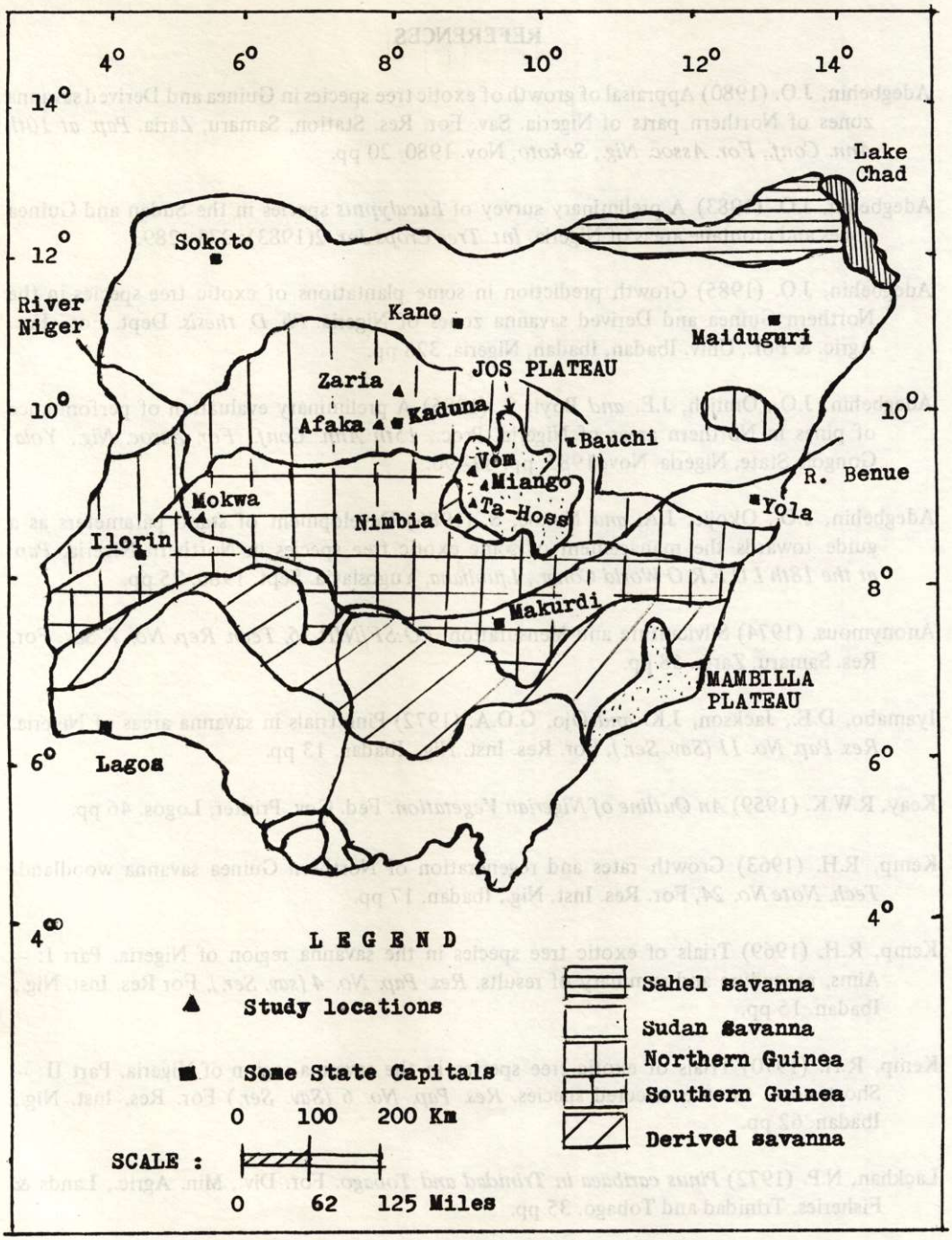

Fig. 1. Map of Nigeria showing the savanna zones (Keay,1959) and the locations of study areas.

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