

Root System of Tropical Trees 2. Features of the Root System of Iroko (*Chlorophora excelsa* BENTH. et HOOK.)

Kořenový systém tropických dřevin 2. *Chlorophora excelsa* BENTH. et HOOK.

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Abstract — In the tropical rain forest of Ghana, Iroko (*Chlorophora excelsa* BENTH. et HOOK.) was found to be a deeply rooted tree with prominent tap-root and vertical sinkers. The surface horizontal roots showed in some cases remarkable forking which may be an initial stage in evolution of knee-roots known in some trees of tropical fresh-water swamps. Estimates of the total root mass layering in the rain forest studied indicated a pronounced concentration of smaller roots in the upper 5 cm soil layer. The contradiction between the prevailing views on root systems of tropical trees, and the results of the present observations are discussed.

Introduction

Among the West African timber trees, Iroko (*Chlorophora excelsa* BENTH. et HOOK.: *Moraceae*) offers some advantageous features for root ecological studies. Its end-roots (i. e. the distal branches consisting of primary tissues) have bright yellow coloration on the primary cortex and the skeleton roots (i.e. the main branches in an advanced stage of secondary growth) have prominent lenticels also with bright yellow markings. These features make for easy recognition in the field. The outstanding importance of Iroko in West African forestry was another reason for our choice in the initial observations of the root system of tropical rain-forest trees.

Two research sites were selected, namely, Esukawkaw Forest Reserve (0°45' W; 6° 20' N) and University of Ghana Agricultural Research Station in Kade (0°55' W; 6°10' N) both situated in the moist semideciduous forest zone with frequent occurrence and regeneration of Iroko.

The method used was a complete or partial excavation of a series of sample trees: 10 seedlings, 1 pole-size tree, 1 mature tree in Esukawkaw Forest Reserve, 30 seedlings and 2 mature trees at Kade. The partial excavations were carried out by the method of "wedge-shaped transect" (JENÍK 1957) which facilitated observation of 2 walls in one soil pit. The separation of the roots from the soil samples was done by a method of successive flotation in wash basins: the soaked soil sample was repeatedly stirred and after sedimentation of heavy mineral particles the roots were sieved out from the water surface. Soil reaction (pH) was determined by the glass electrode method on soil water suspensions, and the field capacity was calculated by expressing the moisture lost from a specific quantity of soil on drying as a percentage of the oven dry weight of the soil (PIPER 1950).

Although the following results are partly quantitative, the technical limitations imposed by this type of study do not permit rigorous statistical treatment.

Table 1
Tap root development in *Chlorophora excelsa* seedlings

Thickness of root collar (mm)	Single tap-root	Forked tap-root	Totals
< 2.6	7	11	18
> 2.6	9	3	12
	16	14	30

Results

Roots of seedlings

In the seedlings the thickness of the root collar seems to be in linear correlation with the height of shoot as well as with the total length of the skeleton roots (compare Fig. 1 & 2)

The degree of branching of roots is low and the tiny distal roots in the surface horizon from an "extensive" type of root system (sensu BÜSGEN 1901).

Excavations in different sites showed that young seedlings of *Chlorophora excelsa* develop a prominent tap-root (see Fig. 3A and Plate II, above). In the compact subsoil, filled with lateritic gravel, this tap-root may fork due to damage to the apex by mechanical resistance of the soil or by insects. In the forest of Kade, 30 excavated seedlings gave results summarized in Table 1.

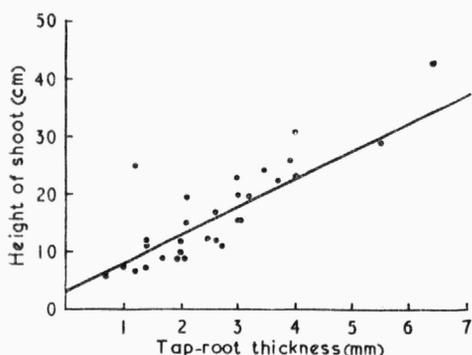


Fig. 1. — Relation between the tap-root thickness at root collar and the height of the shoot of seedlings of *Chlorophora excelsa* in the rain forest near Kade.

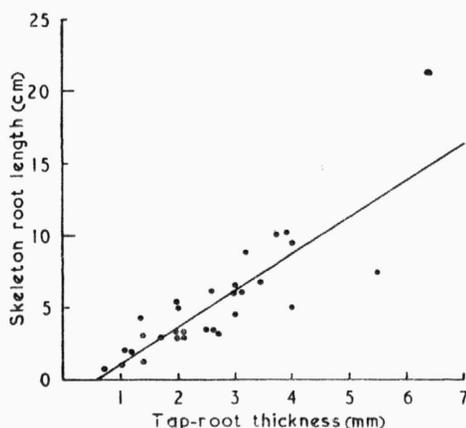


Fig. 2. — Relation between the tap-root thickness at root collar and the total length of skeleton roots (above 1 mm thickness) of seedlings of *Chlorophora excelsa* in the rain forest near Kade.

There appears, from the table, to be a tendency for larger seedlings to have a single tap-root and smaller seedlings a forked tap-root. A possible explanation for this difference would be that a single tap-root may lead to better growth and/or better survival than a forked tap-root. However, since a chi square test gave a value of 2.46 which was not significant at the 5% level, these results should be regarded as provisional.

Anatomically all roots including the biggest tap-root seem to start with a diarch stele lacking pith. Large metaxylem vessels later occupy the central part of the root. The primary cortex contains conspicuous fibres and the periderm starts forming much later than the vascular cambium. No evidence was found of root hairs on the distal roots in the surface soil, nor did a careful search reveal any evidence of mycorrhizae.

Pole and mature trees

Successive growth of Iroko trees is accompanied by vigorous development of horizontal roots which run far beyond the vertical projection of the crown. Their thickness generally does not exceed that of the tap-root which remains the main skeleton root and the main 'axis' of the root system (see Fig. 3 B). As far as we observed, the network of the end-roots of this species does not concentrate in the humus layer, which is mostly occupied by roots of forest undergrowth trees and climbers.

The wedge-shaped transect observations revealed that the final stage of root skeleton development may be sketched as in Fig. 3 C. The bulk of the root mass of the skeleton roots is represented by the big horizontal roots which creep closely under the surface, occasionally protruding above the surface of the soil (Plate II., below).

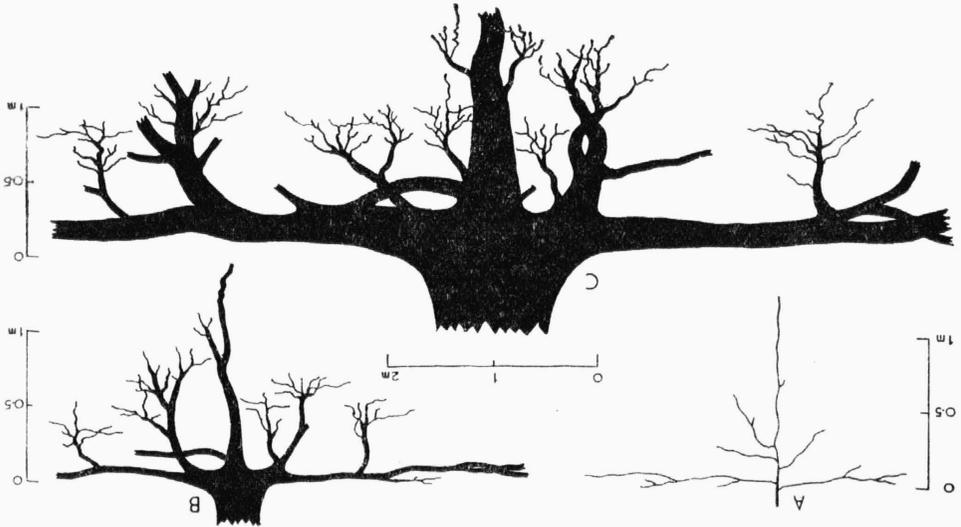


Fig. 3. — Schematic representation of the morphogenesis of the root system of *Chlorophora excelsa* in the rain forest of Ghana; A — seedling, B — pole tree, C — mature tree.

There are no buttresses even in the largest Iroko trees, but only slight root spurs, reaching up to 7 metres or less develop at the base of the stem. These spurs continue as the biggest horizontal roots in the surface soil. A mature tree forms 5 to 7 main horizontal roots.

An interesting feature of these horizontal roots was observed in Kade (see plate III., above): they follow an undulating course and at points where they reach the greatest depth a fork occurs which gives rise to a sinker and a branch which grows towards the surface. This forking occurs repeatedly on the same root and suggests a sort of environmental modification (adaptation) to badly aerated lateritic soils. It seems to be the same sort of adaptation which finds its pronounced form in knee-root formation of some swamp trees, such as *Mitragyna ciliata* and *Symphonia globulifera*.

The production of small roots seemed to be always scanty in the immediate surroundings of the stem and bright yellow end-roots were scarcely recorded in the surface horizon.

A well developed tap-root was present in all mature trees excavated in Esukawkaw Forest Reserve and the Agricultural Research Station at Kade (see Plate III., below). Though the small number of trees does not allow much generalization it seems at least certain that in Iroko there is a genetic predisposition to tap-root formation. A mighty tap-root remained as the biggest vertical skeleton root even in the largest tree measured (about 3.5 metres in girth). We could not follow the full depth of its penetration, however, but it is probable that this depth far exceeds 2 metres.

As a continuation of the spurs big vertical or slightly inclined sinkers are formed (see Plate II., Phot. 2). These presumably contribute substantially to the stability of the giant trees which grow up to 40 metres or more in height. Along the main horizontal roots a set of smaller vertical or more sloping sinkers occur. At an average depth range of about 50 to 100 cm all these sinkers branch into broom-shaped structures which may be a morphological response to the unfavourable soil texture (lateritic gravel) and bad aeration.

Root mass layering on the Iroko sites

In order to get a quantitative estimate of the general root mass distribution on the Iroko sites, we washed out, graded into thicknesses, and weighed all roots regardless of species from soil

Table 2

Soil and root mass layering on *Chlorophora* sites; the root mass is expressed in g per 6250 cm³ of soil; only roots under 2 mm thickness are included

soil layer cm	Esukawkaw			Kade No 1			Kade No 2		
	pH	field capacity %	root mass	pH	field capacity %	root mass	pH	field capacity %	root mass
0—5	6.0	34.3	34.3	4.8	27.9	33.3	4.4	23.3	25.9
5—10	5.4	20.2	15.8	4.7	13.0	7.4	4.2	28.9	10.5
10—20	4.8	19.9	4.0	5.2	14.3	5.0	4.4	10.8	7.3
20—30	4.9	15.8	0.1	5.0	16.3	2.7	4.5	8.9	1.4
30—40	4.8	16.7	0.1	5.1	11.7	1.7	4.7	9.0	0.9
40—50	4.8	16.7	0.1	4.9	14.5	1.4	7.2?	9.2	0.8

blocks sampled from the following layers: 0 to 5 cm, 5 to 10 cm, 10 to 20 cm, 20 to 30 cm, and 40 to 50 cm. The soil blocks measured 25 by 25 cm in cross section and were of the thicknesses mentioned above. They were collected away from the big skeleton roots at a distance of 2 to 3 metres from the base of the trunk.

In Table 2, the mass of roots under 2 mm thickness is compared with other soil properties and Figs. 4, 5 and 6 show the total root mass layering with grading according to the root thickness.

The roots under 2 mm thickness are most suitable for the ecological evaluation of the root layering as they may be taken to represent the physiologically active part of root systems. Although it is true that a number of the end-roots may be lost during the washing process the roots measured by these techniques belong to the distal branches which bear the true end-roots.

The marked feature of the layering in the three sites is the sharp decrease of the root quantities even in the 5 to 10 cm horizon: in all cases it is less than half the quantity in the surface layer. There appears to be a relationship between this decline in root mass, with increasing depth, and field capacity,

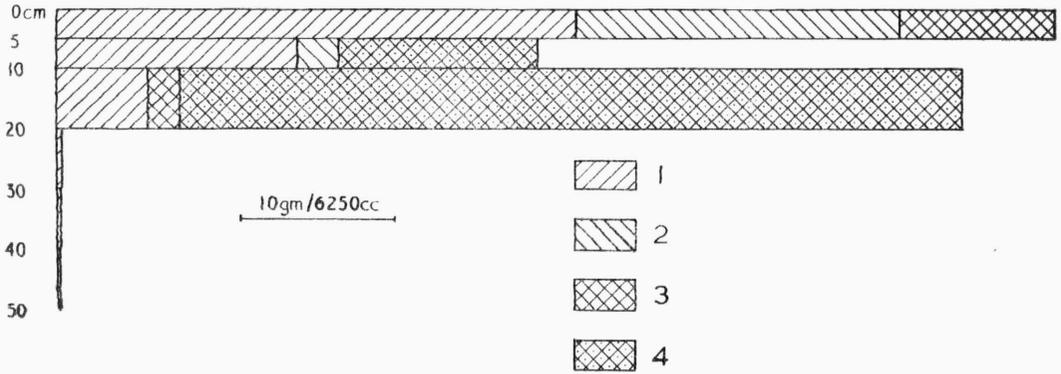


Fig. 4. — Total root mass layering (regardless of species) on the *Chlorophora excelsa* site in the Esulawkaw Forest Reserve; monolith taken at 2 m away from the base of a *Chlorophora* stem; 1 — root thickness under 2 mm, 2 — root thickness 2 to 5 mm, 3 — root thickness 5 to 10 mm, 4 — root thickness above 10 mm. The length of the abscissa equals 10 g per 6250 cm³.

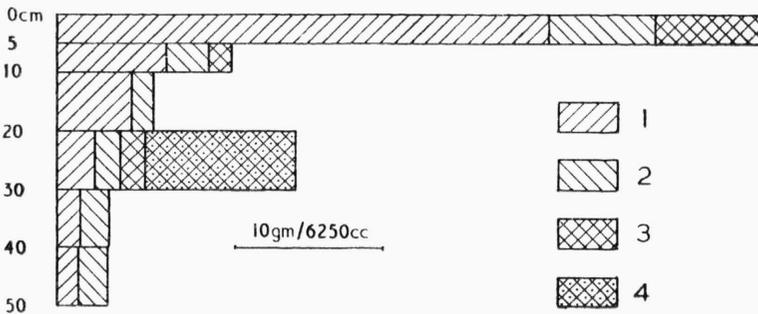


Fig. 5. — Total root mass layering (regardless of species) on the *Chlorophora excelsa* site No. 1 in the rain forest near Kade; position of monolith, scale and root categories as in Fig. 4.

which decreased similarly, but no doubt other features of the soil play a part, such as humus content and pedogenic processes which differentiate the soil profile. Except in Esukawkaw Forest Reserve, there was no obvious relationship between root mass and pH in the various soil layers.

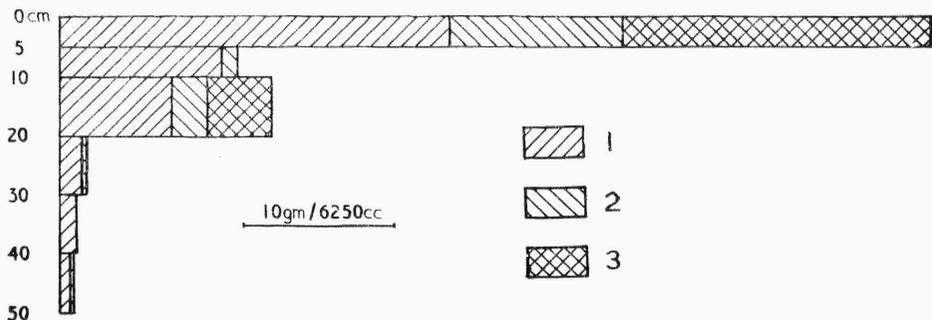


Fig. 6. — Total root mass layering (regardless of species) on the *Chlorophora excelsa* site No. 2 in the rain forest near Kade; position of monolith, scale and root categories as in Fig. 4.

The bigger skeleton roots vary in their quantities considerably as one moves away from the stem base. The observation in the transects and the soil analyses suggest that there are not many skeleton roots in the spaces between the trees, under 50 to 70 cm depth, where the field capacity approaches 10%; this is the level where 'broom-shaped' forms of roots of *Chlorophora excelsa* occur frequently.

We could not undertake the tedious task of separation of *Chlorophora* roots from the general root mass. However, their conspicuous coloration allows a conclusion that they are rather scanty in the surface layer, even close to the Iroko stem where the prevailing roots belong to the undergrowth trees and climbers.

Discussion

These observations of the Iroko root system show some trends which do not agree with the prevailing view on root system of tropical trees in general (SCHNELL 1950, p. 20; AHN 1960; TAYLOR 1960, p. 22) and on the root system of the species studied, in particular (FOGGIE 1957, p. 135). The central part of the root skeleton of *Chlorophora excelsa* gives an appearance of a deeply rooted tree comparable with the tap-root and sinker root systems of such temperate trees as European oaks (compare JENÍK 1957). Young seedlings and saplings develop a prominent tap-root (see also TAYLOR 1960, p. 248 to 249) which remains the leading vertical root even at maturity of the tree, which is again a development similar to that of oaks. A large tap-root and big sinkers near the stem base seem to be sufficient means of anchoring for an emergent tree lacking buttresses. Though the total root mass of smaller roots on *Chlorophora* sites is prominently concentrated in the surface 5 cm layer, this criterion does not adequately reflect the depth of rooting of *Chlorophora excelsa* itself.

Hitherto the evaluation of the rooting depth of tropical trees has been chiefly based on causal observation of wind blown trees. Although convenient for study, such trees may be expected to be more shallow rooted than normal. Additional source of information about roots in the tropics are the soil surveys. The soil survey data are derived from soil pits which are, for convenience, located outside the spread of the main skeleton roots of trees. Thus, these data reflect only the layering of the smaller roots which are concentrated in the humus horizon in the spaces between trees as our data confirm. Since the humus layer in tropical rain forest is in general shallower than in the temperate forests, the maximum concentration of roots is slightly more conspicuous than in say, the European condition. It is perhaps only in this sense that we may speak about greater shallow-rootedness of tropical trees. Many more excavations and quantitative measurements are needed, however, before a firm picture can be established.

Acknowledgements

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Summary

■ Výzkum kořenového systému u *Chlorophora excelsa* BENTH. et HOOK. v tropickém deštném lese v Ghaně ukázal, že tento strom 1. velikosti vytváří v lateritických půdách mohutný kulový kořen a silné kotevní kořeny. U horizontálních kořenů bylo pozorováno větvení do vidlice, která se zdá být vývojovým stupněm ke kolenovitým kořenům bažinných tropických stromů. Prokořenění lesní půdy drobnými kořeny je v prostorech mezi stromy zřetelně soustředěno do povrchové vrstvy mocné přibližně 5 cm. Výsledky pozorování jsou porovnány s převažujícími údaji o mělkokořenosti tropických stromů.

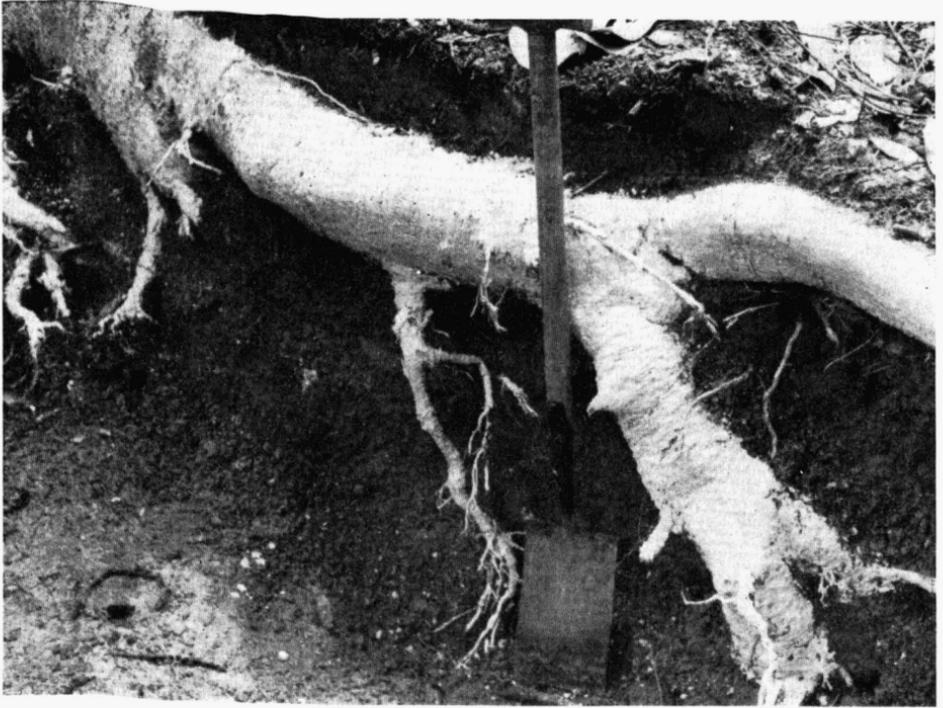
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See also Plate II and III in the appendix.



Above: prominent tap-root of *Chlorophora excelsa* seedling (Esukawkaw Forest Reserve).
 Below: main horizontal root of *Chlorophora excelsa* with a thick sinker which is continuous with the root spur (site No. 1 near Kade); roots painted white for easy recognition.



Above: main horizontal root of *Chlorophora excelsa* with a typical forking into a surface branch and sinker (site No. 1 near Kade).

Below: central part of the root skeleton of a mature *Chlorophora* tree with a prominent tap-root pointed by the tip of the cutlass (site No. 2 near Kade).