# SHOOT AND ROOT CHARACTERS IN SOME *Coffea* SPECIES[1] /

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Resumen

*Las plantas de tres años y medio de edad de siete especies* Coffea *y tres linajes fueron estudiadas para quince características de los tallos y quince características de las raíces, y cuatro relaciones entre la raíz y el tallo (largo, extensión, peso fresco y peso seco)en el Central Coffee Research Institute India (13°22'N, 75°28'E).*

*En la fase del crecimiento y la localidad escogida para el estudio,* Coffea arabica *L. Cv. S. 795 mostró el mejor crecimiento para el tallo, mientras que* C. canephora, C. congensis, C. excelsa *y* C. dewevrei *indicaron el mayor crecimiento para la raíz.*

*El largo del tallo, peso fresco del tallo fueron más altos que los de la raíz en todas las especies estudiadas.*

*La relación más alta del largo para la raíz pivotante al del tallo en* C. eugenioides *y* C. bengalensis *comparados con otras especies se asumió para indicar la mejor adaptabilidad de las dos especies a las condiciones de la sequía.*

*Al discutir sobre las limitaciones del estudio se sugirió la necesidad de una exploración nueva en el habitat natural de las especies* Coffea.

## Introduction

Study of shoot and root systems has a great influence not only on cultivation aspects, but also on plant selection. In coffee, studies on root systems and effects of soil-conditions and cultural practices have been undertaken mainly on *C. arabica* and *C. canephora,* (9, 11, 12, 13, 14) while other species have received comparatively little attention.

The present study was undertaken to understand the shoot and root characters of various *Coffea* spp. established at Central Coffee Research Institute. The two commercially cultivated species *C. arabica* and *C. canephora* were also included for comparison.

## Materials and methods

Seedlings of seven species and three races of *Coffea* namely *C. arabica* CV S.795, *C. canephora* subvar. robusta CV.s.274, *C. congensis, C. eugenioides, C. bengalensis, C. liberica, C. dewevrei* and its races *excelsa, arnoldiana,* and *aruwimiensis* classified according to Chevalier (4) were selected. The seedlings were planted 22 cm apart at the nursery of Central Coffee Research Institute, India (Latitude 13°22'N; Longitude 75°28'E) on 15 cm raised beds of about 6 x 1 m length and breadth. The beds were

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made by mixing 6 forlits of virgin forest soil, 2 forlits of compost, 2 kg of fine sieved agricultural lime and 400 g of rock phosphate. The soil pH of the beds was in the range of 6.4-6.7. Forty seedlings were raised for each species. Watering was done as and when necessary and nitrogen in the form of urea or ammonium sulphate was supplied at 15 days interval to all the seedlings. The meteorological data of the locality during the growth period of the seedlings are given in Table 1. The plants were uprooted when they were three and a half years old, by digging trenches around each bed. The soil around individual roots was loosened by washing with a jet of water from a hand driven *Gattar* sprayer operating at a pressure of 10 kg/cm$^2$ along the path. Care was taken to minimise the damage to smaller roots and whenever it was unavoidable, the broken segments were fastened with a thread to the respective root. Immediately after uprooting, the superficial moisture present on the plant parts was removed with a blotting paper. Five plants per species were sampled. The stem was separated from the root portion by cutting with a secature/saw at the soil level.

Count of primaries, nodes on stem as well as branches was taken followed by measurements of length of stem and branches. The circumference of stem was determined at a distance of 7.5 cm from the base of stem. An average value of three readings was taken as the measure of stem circumference. Leaf length (L), breadth (B) and L/B ratio were also taken.

For the root characters, data on the total number of main roots, density of secondary roots, weight of total roots and weight of feeder roots was determined. During the process of measuring, a loss of fine roots to the extent of 10 to 15% of the total was unavoidable. Shoot and root parts were dried at a constant temperature of 105°C in an electric oven. Three constant weights were taken as an index of optimum drying. Fresh and dry weight of leaves were determined separately.

For observation of root morphology, the classification of coffee root system given by Bull (2) was followed. According to this classification, basically the normal coffee root system comprises one or more main vertical roots (taproot), the roots which radiate from the base of the stem and spread parallel to the soil surface (laterals) and the laterals which originate from below the point at which the taproot begins to taper abruptly (tap-laterals). The roots in the above categories were sub-divided into primary and secondary roots on the basis of root diameter (12).

Vegetative character means were calculated for each species and the analysis of variance was done for each character comparing the variation between species with that within the species. Character associations in each species were determined using Spearman's rank correlation coefficient (6).

## Results and discussion

Variance between species was significant when compared with the variance within species for all the characters indicating significant differences in character means between species.

Shoot characters: (Tables 2 and 3)

*Congensis, canephora, dewevrei* and *excelsa* had greater stem length, diameter of stem, primaries and higher fresh weight of shoot compared to all other species. *C. arabica* showed the highest number of nodes, primaries, nodes per primary and length per primary. *C. bengalensis* and *C. eugenioides* had low values for most of the characters except total nodes, number of primaries, nodes per primary and dry matter percentage. Longest internodes were seen in *liberica* and *arnoldiana* while *arabica* had medium internodal length; *eugenioides* had the shortest internodes.

**Table 1. Meteorological data pertaining to the locality during the growth period of the seedlings.**

| | 1973 | 1974 | 1975 | 1976 |
|---|---|---|---|---|
| Av. Max. Temperature (°C) | 28.8 | 28.5 | 28.2 | 29.1 |
| Av. Min. Temperature (°C) | 17.6 | 16.8 | 15.9 | 16.6 |
| Average Relative Humidity (%) | 80.0 | 81.0 | 85.0 | 88.0 |
| Rainfall (mm) | 2 369.2 | 2 328.0 | 3 157.9 | 1 764.6 |

Table 2. Comparative shoot characters of selected *Coffea* species at 3-1/2 years growth.

| Species | Stem length (cm) | Stem Circum-ference (cm) | Nodes on stem | Total nodes on shoot | Leaf Length (cm) | Leaf breadth (cm) | Leaf Length breadth | Number of primaries | Length of primary (cm) | Shoot spread (cm) | Interno-dal length on primary (cm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Arabica* | 115.4 | 4.9 | 21.8 | 261.8 | 12.3 | 4.7 | 2.58 | 22.4 | 30.0 | 86.0 | 3.88 |
| *Canephora* | 138.4 | 6.2 | 19.0 | 91.6 | 21.9 | 8.6 | 2.57 | 17.8 | 30.2 | 70.6 | 7.82 |
| *Congensis* | 159.7 | 6.4 | 19.0 | 151.9 | 14.8 | 5.7 | 2.63 | 22.6 | 34.9 | 78.0 | 6.12 |
| *Excelsa* | 121.4 | 7.2 | 13.5 | 71.5 | 27.5 | 11.2 | 2.45 | 13.5 | 27.5 | 62.8 | 7.45 |
| *Liberica* | 117.7 | 3.9 | 11.0 | 32.7 | 25.5 | 10.4 | 2.50 | 6.8 | 22.6 | 47.2 | 9.09 |
| *Arnoldiana* | 110.8 | 5.7 | 12.6 | 32.6 | 23.7 | 9.9 | 2.45 | 8.2 | 19.5 | 52.8 | 8.48 |
| *Aruwimiensis* | 111.66 | 5.9 | 13.8 | 49.8 | 23.5 | 9.8 | 2.40 | 9.2 | 22.5 | 67.2 | 7.23 |
| *Dewevrei* | 134.5 | 6.2 | 20.2 | 103.0 | 21.5 | 9.4 | 2.29 | 19.0 | 29.3 | 79.2 | 6.74 |
| *Bengalensis* | 37.7 | 3.6 | 12.4 | 152.0 | 7.8 | 3.1 | 2.61 | 14.0 | 17.6 | 51.0 | 2.76 |
| *Eugenioides* | 28.5 | 1.1 | 12.0 | 94.8 | 6.6 | 2.1 | 3.18 | 9.4 | 3.7 | 12.8 | 1.07 |

Leaf size was maximum in *excelsa* followed by *liberica; eugenioides* had the smallest leaves. Length to breadth ratio of the leaves was highest in *eugenioides* indicating narrow linear leaves, and lowest in *dewevrei* indicating broad leaves. Leaf length was more than twice the leaf breadth in all the species.

Stem diameter and shoot fresh weight was significantly correlated in *dewevrei, excelsa, eugenioides, bengalensis* and *arabica*. Awatramani and Subramanya (1) reported a similar positive correlation between stem girth and shoot fresh weight in *arabica*. Number of nodes was positiviely correlated with number of primaries in *liberica, canephora* and *aruwimiensis*. These species were also characterized by lesser number of nodes per primary and longer internodes. Length of primary was positively correlated with shoot fresh weigth 9in *liberica, arabica, canephora* and *arnoldiana* Awatramani and Subramanya (1) found a similar positive correlation in 9-10 year old plants of *arabica*

Root characters: (Table 4)

Taproot length, number of primary roots and total length of primary roots was more in *dewevrei* and *excelsa* compared to other species. However,

Table 3. Shoot fresh weight and dry matter (%) in *Coffea* species.

| Species | Fresh wt stem + primaries (g) | Dry matter (%) | Leaf fresh weight (g) | Dry matter (%) |
|---|---|---|---|---|
| *Arabica* | 204.7 | 36.15 | 0.96 | 32.29 |
| *Canephora* | 287.9 | 49.83 | 2.47 | 30.36 |
| *Congensis* | 305.4 | 41.78 | 1.30 | 35.38 |
| *Excelsa* | 267.6 | 52.02 | 5.65 | 34.51 |
| *Liberica* | 164.3 | 35.48 | 4.98 | 34.14 |
| *Arnoldiana* | 159.6 | 33.27 | 4.79 | 34.24 |
| *Aruwimiensis* | 136.3 | 59.28 | 5.26 | 30.80 |
| *Dewevrei* | 269.2 | 41.90 | 3.36 | 40.18 |
| *Bengalensis* | 27.4 | 49.64 | 0.39 | 23.08 |
| *Eugenioides* | 3.7 | 45.95 | 0.21 | 28.57 |

Table 4. Comparative root characters of selected *Coffea* species at three and a half years from seed.

| Species | Tap root length (cm) | Tap root circum-ference | Lateral root number | Lateral root | | | Tap laterals | | | Tap secondaries | | | Root fresh wt. (g) | % dry matter | Feede root dry wt. (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Av. Leng-th (cm) | Maximum length (cm) | Secon-daries per cm | Number | Av. leng-th (cm) | Secon-daries per cm | Number | Av. leng-th (cm) | Secon-daries per cm | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| *Arabica* | 37.8 | 5.6 | 7.5 | 27.4 | 38.0 | 0.92 | 6.0 | 19.6 | 1.83 | 2.2 | 27.2 | 2.57 | 118.9 | 27.25 | 8.20 |
| *Canephora* | 55.1 | 6.5 | 8.8 | 22.7 | 27.0 | 0.93 | 8.8 | 29.4 | 2.14 | 1.8 | 23.8 | 1.42 | 182.4 | 38.65 | 19.18 |
| *Congensis* | 51.5 | 6.8 | 6.0 | 24.7 | 32.4 | 1.70 | 15.0 | 21.2 | 1.20 | 2.2 | 28.0 | 0.93 | 159.7 | 41.52 | 10.80 |
| *Excelsa* | 65.2 | 7.6 | 5.6 | 37.6 | 60.4 | 1.63 | 10.7 | 35.2 | 0.75 | 1.4 | 57.5 | 2.93 | 231.1 | 43.27 | 11.80 |
| *Liberica* | 46.2 | 5.8 | 9.0 | 19.2 | 25.8 | 2.04 | 3.0 | 28.1 | 1.30 | 2.6 | 34.8 | 2.00 | 93.5 | 29.73 | 3.20 |
| *Arnoldiana* | 53.1 | 6.3 | 8.7 | 28.9 | 38.2 | 2.10 | 6.8 | 21.9 | 2.42 | 2.6 | 34.5 | 2.53 | 72.3 | 42.60 | 2.45 |
| *Aruwimiensis* | 53.8 | 6.2 | 8.7 | 32.2 | 55.8 | 1.81 | 8.5 | 23.0 | 1.08 | 1.8 | 35.6 | 2.18 | 94.0 | 57.23 | 9.19 |
| *Dewevrei* | 71.5 | 6.7 | 9.0 | 29.1 | 34.0 | 1.83 | 7.7 | 32.3 | 1.23 | 3.0 | 47.5 | 1.45 | 128.9 | 43.06 | 6.26 |
| *Bengalensis* | 33.7 | 2.6 | 3.0 | 19.4 | 25.0 | * | 4.0 | 14.8 | * | * | * | * | 37.7 | 25.99 | 1.25 |
| *Eugenioides* | 18.3 | 1.3 | 3.0 | 13.0 | 16.0 | * | 3.0 | 12.6 | * | * | * | * | 4.0 | 40.00 | * |

* Components present in negligible quantity.

the concentration of secondary roots was more in *arnoldiana* and *liberica* compared to other species. Fresh weight of roots was maximum in *excelsa* followed by *canephora*. Dry matter percentage was maximum in *aruwimiensis* followed by *dewevrei* and *excelsa*. Total weight of feeder roots was more in *canephora* and *excelsa* compared to other species.

Correlations among root characters were mostly nonsignificant except for a positive correlation between (1) lateral root length and fresh weight of root (2) lateral root length and feeder root weight (3) fresh weight of root and feeder root weight in *liberica*.

Root-shoot relationship: (Table 5)

Stem length was more than taproot length in all the species. It was thrice the taproot length in *arabica, congensis* and *liberica*, twice in *canephora, excelsa, arnoldiana, aruwimiensis* and *dewevrei* and in the neighbourhood of unity in *bengalensis* and *eugenioides*. Shoot spread was more than that of root in *arabica, bengalensis* and *eugenioides*, while root spread was more in *canephora, excelsa, arnoldiana* and *aruwimiensis*. Both shoot and root had almost equal spread in *congensis, liberica* and *dewevrei*.

Fresh weight of shoot was in general more than that of root in all the species except in *bengalensis* and *eugenioides*, which had higher root fresh weight than shoot (Table 4). Dry weight of shoot was invariably more than the dry weight of root in all the species with maximum ratio in *congensis* and minimum in *eugenioides*. Dry matter percentage was also more in the shoot compared to root in all the other species except *arnoldiana* and *dewevrei*, in which reverse was the case. Stem diameter was positively correlated with root fresh weight in *dewevrei, arnoldiana* and *bengalensis*. Total nodes on shoot was positively correlated with taproot length in *excelsa, arabica* and *aruwimiensis*. Lateral root length, fresh weight of root and weight of feeder roots were positively correlated with total nodes on shoot and number of primaries in *liberica*. Shoot fresh weight was positively correlated with that of root in *dewevrei, arabica, arnoldiana, aruwimiensis* and *bengalensis*.

## Conclusions

The following salient points emerge from the present study:

1. The best shoot growth was observed in *arabica* followed by *congensis*.
2. The best root growth was found in *canephora, congensis, excelsa* and *dewevrei* in that order.
3. Best growth of shoot in relation to root was seen in *congensis* followed by *arabica* and *liberica* which may therefore be considered as 'faster-growing' compared to the other species.
4. When compared with commercially cultivated species, *arabica* and *canephora*, superior growth of shoot and root is noticed in *congensis, excelsa* and *dewevrei*. Therefore these species may be useful for hybridization with the cultivated species to obtain better plant types. From a study of flower number in *Coffea* species, Vishveshwara and Ahmed (17) found that *dewevrei, arnoldiana, canephora* and *laurentii* were superior to arabica

**Table 5.** Root-shoot ratio in selected *Coffea* species at three and a half years from seed.

| Species | Tap root lenght / Stem lenght | Shoot spread / Root spread | Shoot fresh wt. / Root fresh wt. | Shoot dry wt. / Root dry wt. |
|---|---|---|---|---|
| *Arabica* | 0.33 | 1.30 | 1.38 | 2.10 |
| *Canephora* | 0.40 | 0.84 | 1.56 | 2.02 |
| *Congensis* | 0.32 | 0.99 | 1.96 | 2.44 |
| *Excelsa* | 0.54 | 0.73 | 1.32 | 1.33 |
| *Liberica* | 0.39 | 1.01 | 1.84 | 2.15 |
| *Arnoldiana* | 0.48 | 0.78 | 2.60 | 1.58 |
| *Aruwimiensis* | 0.48 | 0.90 | 2.23 | 1.57 |
| *Dewevrei* | 0.53 | 1.09 | 2.15 | 2.05 |
| *Bengalensis* | 0.89 | 1.52 | 0.67 | 1.36 |
| *Eugenioides* | 0.64 | 1.48 | 0.96 | 1.06 |

for number of flowers per node and therefore merited exploitation by hybridization.

The species combining superior vegetative characters as found in the present study and high flower number as found by Vishveshwara and Ahmed (17) is *dewevrei*, which therefore merits exploitation.

5. The taproot length versus hypocotyl length has been used as an index of adaptability to certain ecological conditions in *Coffea* species (5). In the present study *congensis* indicated minimum ratio supporting the conclusion of Dublin (5); *arabica* also had a low ratio; however, *C. eugenioides* had a higher ratio from that reported by Dublin (5) indicating that it is adaptable to dry conditions, at least in India. *C. bengalensis*, a species indigenous to India, showed highest ratio indicating its similar adaptability to dry conditions.

The taxonomy of *Coffea* species suggested by Chevalier (4) is generally supported by this study. *C. arabica* differed from the other species (*C. congensis* and *C. canephora*) of the sub-section Erythrocoffea in a number of characters like shoot length, leaf size, total nodes, internodal length, taproot length and percentage dry matter. Nevertheless, based on crossability, Carvalho and Monaco (3), suggested close affinities between the above three species as well as *C. eugenioides* and suggested transferring of *C. eugenioides* from sub-section Mozambicoffea to Erythrocoffea.

*C. dewevrei* was classified by Chevalier (4) under sub-section Pachycoffea along with its races, *excelsa, sylvatica, zenkeri, aruwimiensis, dybowskii, ituriensis, excelsoidea* and *neo-arnoldiana*. The collection of *C. dewevrei* now studied was introduced from Guatemala in 1953. It resembles race *ituriensis* in leaf, flower and fruit characters. Carvalho and Monaco (3), based on crossability, indicated that *dewevrei* seems to be closer to *canephora* and *congensis* than *liberica*.

Due to insufficient knowledge on the purity and distribution of *Coffea* species in Africa, where overlapping between species is known to occur (3), the studies on restricted specimens of 'introduced species' established at various institutes provide partial information on relationship between species. This lacuna can be overcome by organising fresh extensive expeditions to natural habitats of *Coffea* species, before civilization completely erodes the germplasm of species and spontaneous hybrids from proper preservation and exploitation in breeding. Krug and De Poerck (10) have drawn similar conclusion from a world survey of the cultivated species and varieties of the genus *Coffea*.

**Summary**

Shoot and root characters were studied in three and a half year-old seedlings of seven *Coffea* species and three races. Vegetative character means were calculated for each species and the analysis of variance was done for each character comparing the variation between species and within the species. *C. arabica* showed best shoot growth whereas *canephora, congensis, excelsa* and *dewevrei* indicated superior root growth. Stem length was more than taproot length in all the species. Similarly shoot fresh and dry weight were higher than root fresh and dry weight in all the species. *C. eugenioides* and *bengalensis* were found to be adaptable to dry conditions based on the ratio of taproot length to stem length. The need for fresh expeditions in natural habit of *Coffea* species is advocated.

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# Reseña de libros

GREENLAND, D. J. (Editor). CHARACTERIZATION OF SOILS in relation to their classification and management for crop production: Examples from some areas of the humid tropics Oxford University Press, Oxford, England, 1981, 446 p.

El conocimiento inadecuado de los suelos de los trópicos húmedos y de su potencialidad para la producción de alimentos, es una de las fuentes de incertidumbre en la toma de decisiones sobre la capacidad del mundo de alimentar su población actual y futura. Con estas palabras el Editor señala, en términos claros, la hipótesis que dio origen al volumen que comentamos, en el cual se pretenden aclarar algunos aspectos importantes del problema así planteado.

La obra contiene 15 capítulos que giran en su mayoría alrededor de los estudios efectuados sobre aspectos diversos, en catorce "toposecuencias" localizadas en el Sur de Nigeria. (Una "toposecuencia" se define como una sucesión de lugares desde una cresta o meseta hasta un valle en la parte más baja).

En el Capítulo 2 se describen las "toposecuencias" seleccionadas, las cuales engloban seis franjas ecológicas con lluvias variables desde menos de 1.100 hasta más de 2.500 milímetros anuales y dos grupos de materiales parentales (rocas cristalinas y rocas arenosas sedimentarias). De cada una de ellas se da una descripción muy detallada y se presenta la clasificación de los suelos que la componen.

En los capítulos siguientes se examinan, para los suelos bajo estudio, la mineralogía de las fracciones arcilla y arena fina; las características químicas; la adsorción y liberación del fósforo; las propiedades físicas; el estado de los micronutrimentos; la transformación del nitrógeno y la materia orgánica; el papel de las micorizas en la asimilación de fósforo y el manejo de esos suelos para la producción continua de cosechas.

Finalmente, se dedica tres capítulos a aspectos generales de los suelos tropicales, no conectados directamente con el estudio de las "toposecuencias" descritas. El primero se refiere al manejo de los suelos en los Oxisoles de sabana y en los Ultisoles de selva en la parte tropical de América Latina; el segundo a la evaluación de la fertilidad potencial y su uso en los trópicos húmedos y el tercero a los sistemas agrícolas y a las cosechas de los trópicos húmedos, en relación con la utilización de los suelos. El libro contiene dos apéndices que describen en detalle tanto los perfiles de los suelos incluidos en las "toposecuencias" como los sistemas agrícolas y las cosechas de los trópicos húmedos en Africa Occidental.

Es laudable el esfuerzo, que este volumen representa, de articular los trabajos de investigación sobre suelos tropicales, de manera que ellos, en primer término, se refieran a zonas concretas y comunes y luego se complementen cubriéndose así una amplia gama de los aspectos más importantes que condicionan las potencialidades productivas de los suelos y que de alguna manera tipifican situaciones de suficiente amplitud para ser de importancia general.

Para América Latina es particularmente interesante el capítulo sobre manejo de los Oxisoles y Ultisoles de sabanas y de selvas tropicales, respectivamente, de Suramérica; estos dos órdenes taxonómicas de suelos cubren 760 millones de hectáreas que son más de la mitad de los terrenos potencialmente arables en esta parte del mundo. Ellos predominan en el cerrado brasileño, y los llanos colombianos y venezolanos (regiones típicas de sabanas tropicales) y en la Cuenca del Amazonas y sus afluentes (región típica de selva tropical).

En el capítulo que a tales suelos se refiere, escrito por Pedro A. Sánchez, de la Universidad de Carolina del Norte (EE.UU), se hace un buen resumen de la bibliografía sobre las características físicas y químicas de estos suelos y su manejo más adecuado en relación con las condiciones críticas que deben corregirse y que son la acidez; la toxicidad de aluminio; la deficiencia de fósforo; el descenso de humedad en las plantas causado por las sequías cortas que ocurren durante la estación lluviosa y la escasez generalizada de casi todos los demás nutrimentos. Las estrategias de manejo que se describen recogen muy bien los resultados de investigaciones llevadas a cabo principalmente en Brasil, Colombia y Venezuela.

Recomendamos la lectura de este valioso libro a todos los interesados en los problemas edafológicos y agronómicos de las regiones tropicales.

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IICA, COSTA RICA, 1982