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# Root characteristics of *Bactris gasipaes* H.B.K.

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## ABSTRACT

The peach palm tree *Bactris gasipaes* H.B.K. is very common in Middle America and South America. It is a very variable plant regarding important ecological and economical factors. Due to its extraordinarily high biomass production and its suitability as "multi purpose" plant (palm heart, fruits, oil, starch, wood, leaf fiber), the plant is used as production factor in the polycultural systems of SHIFT-ENV 23 project.

Results on morphology, biology, and anatomy of the peach palm tree are described in this study.

The polyarchic root systems of the first, second and third order have no fine roots. The exodermis consists of extraordinary large-lumen cells of a maximum diameter of 120 µm, which are located at the basis on small, axially expanded hypodermis cells. The exodermis cells are closely adjoined, but they are not junctioned at the side. They form a very large contact surface. The surface area which is formed by this structure is 2 to 2.5 time larger than the corresponding surface of a root cylinder. This surface area enlargement corresponds to the surface area enlargement caused by root hair in other plants having the factor of 1.5 to 2.9.

## RESUMO

A pupunheira (*Bactris gasipaes* H.B.K.), amplamente distribuída nas Américas Central e do Sul, apresenta alta variabilidade em importantes características ecológicas e econômicas. Devido à sua vigorosa produção de biomassa e seus múltiplos usos (palmito, folhas, frutos, óleo, amido e madeira) foi incluída como um fator de produção no SHIFT-ENV 23: experimento de policultivo.

A morfologia, histologia e anatomia das raízes têm sido estudadas com microscópio de luz e microscopia eletrônica de transmissão, usando-se "seedlings" com três a seis meses de idade e amostras de raízes de árvores com três anos de idade.

Em plantas adultos, o sistema radicular forma ummanto de raízes com 20 cm a 30 cm de espessura, distribuído mais que 5 m radialmente em torno do caule. O sistema radicular consiste de radicelas de vida curta substituídas por raízes primária adventícias, secundárias e terciárias. Raízes quaternárias raramente têm sido encotradas.

As raízes poliárquicas de todas as ordens (n = 1 a 3) não contém raízes finas. A exoderme consiste de células arredondadas muito grandes com até 120 µm em diâmetro, basicamente aderidas a pequenas células da camada hipodérmica. As células exodérmicas adjascentes não estão fixas uma à outra por parede celular rígida, mas por pequenos espaços capilares abertos.

A superfície formada pelas peredes externas das células exodérmicas é mais larga que a área superficial, calculada sobra a base do diâmetro da raízes, assumindo a raiz um formato cilíndrico. O aumento da superficie ativa causada pela estrutura da célula exodérmica é cerca de 2 a 2,5 vezes. Isto corresponde a um aumento da superfície das raízes causado pelas radicelas, as quais estão na faixa de 1,5 a 2,9 vezes.


## ZUSAMMENFASSUNG

Die Pfirsichpalme *Bactris gasipaes* H.B.K. ist in Mittel- und Südamerika weit verbreitet. Sie ist sehr variabel in Hinsicht auf wichtige ökologische und ökonomische Faktoren. Wegen der außerordentlich hohen Biomasseproduktion und der Eignung als "multi purpose" Pflanze (Palmherzen, Früchte, Öl, Stärke, Holz, Blattfasern) wurde die Pflanze als Produktionsfaktor in die Polykultursysteme des SHIFT-ENV 23 Projektes einbezogen.

Dieser Artikel liefert Ergebnisse über Morphologie, Biologie und Anatomie der Wurzeln.

Die polyarchen Wurzelsysteme der 1. bis 3. Ordnung weisen keine Feinwurzeln auf. Die Exodermis besteht aus außerordentlich großlumigen Zellen bis zu 120 µm Durchmesser, die an der Basis auf kleinen, axial langestreckten Hypodermiszellen aufsitzen. Die Exodermiszellen grenzen eng aneinander, sind aber seitlich nicht verwachsen. Sie bilden eine sehr große Kontaktoberfläche zwischen Pflanze und Bodenlösung. Die durch diese Struktur erzeugte Oberfläche ist 2 bis 2,5 mal größer als die entsprechende Oberfläche eines Wurzelzylinders mit vergleichbarem Durchmesser. Diese Oberflächenvergrößerung entspricht der bei anderen Pflanzen durch Wurzelhaare erzeugten Oberflächenvergrößerung mit dem Faktor 1,5 bis 2,9.


## INTRODUCTION

*Bactris gasipaes* H.B.K. (pupunha or chontaduro) is the most widely used palm in Latin America. Already in precolumbian times it was distributed throughout the Amazon basin, the Northern Andean states and Middle America (Figure 1). All plant parts are used for various reasons. The root is taken as a vermifugous agent, the trunk for wood production, fallen flowers are used as preservatives, from leaves sieves, roofs, and other objects are formed. The fruits are either eaten cooked in water or oil or are used as a source for oil or starch production. The fruit production of this semidomesticated plant reaches 12 to 15 tons per ha and year. The production of palmito, palm heart is about 3 tons per ha and year (Chala 1993). The fruit weight and other characteristics vary strongly. A classification system for *Bactris* varieties is based on fruit and seed weight (Table 1).

The peach palm is of high importance for the development of polyculture systems in the humid tropics. Besides the wide range of climatic regimes in which this palm is developing well it also reveals a wide range of very positive agroecological features. The peach palm is compatible in culture with many other perennial plants.

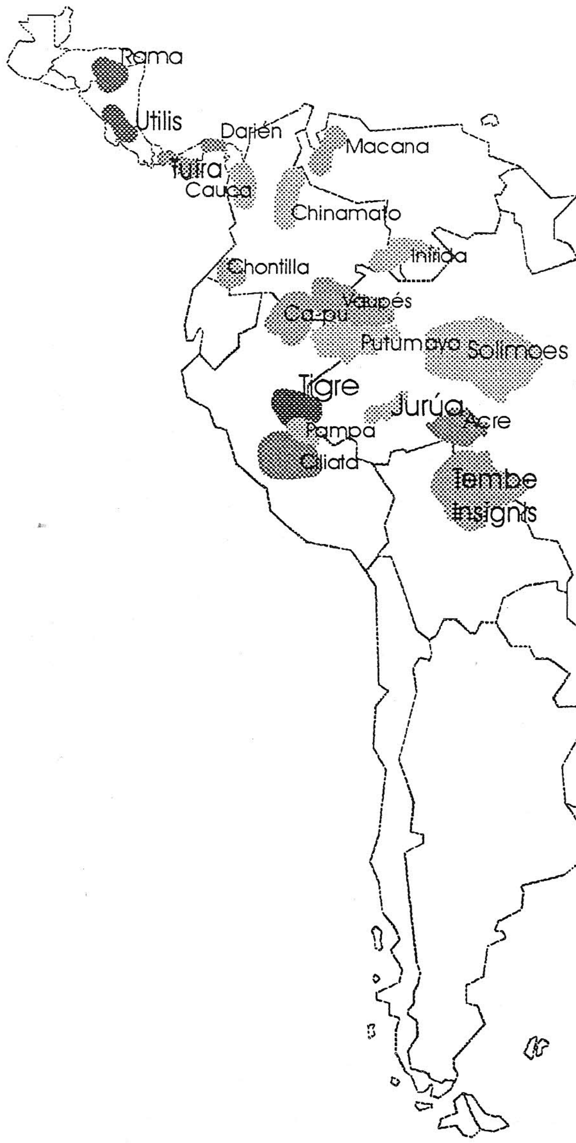


**Figure 1**: Geographical distribution of peach palm groups (modified after Mora Urpí 1993)

**Table 1:** Classification of *Bactris gasipaes* (after Mora Urpí 1993)

| Name | country of origin | fresh mass fruit | fresh mass seed |
|---|---|---|---|
| | | Microcarpal | |
| Acre | Brazil | 1,2 g | < 1 g |
| Ca-pu | Colombia | 8,6 g | ~ 2 g |
| Ciliata | Peru | 4,4 g | 1,6 g |
| Insignis | Bolivia | 5,6 g | 1,7 g |
| Chontaduro | Colombia | 8,7 g | 1,4 g |
| Chontilla | Ecuador | 5,5 g | 2,0 g |
| Darién | Panama | ~ 2 g | ~ 1 g |
| Macana | Venezuela | - | - |
| Caribea | Colombia | - | - |
| Tembe | Bolivia | 11,95 g | 1,71 g |
| Pará | Brazil | ~ 20 g | 2,56 g |
| Juruá | Brazil | ~ 20 g | ~ 2,5 g |
| Cauca | Colombia | ~ 18 g | ~ 2,5 g |
| Tuira | Panama | 18,3 g | 2,6 g |
| | | Mesocarpal | |
| Pampa | Peru | 36,4 g | 2,5 g |
| Pastaza | Ecuador | 23,0 g | 2,6 g |
| Solimoes | Brazil | 41,9 g | 4,05 g |
| Inírida | Colombia | 62,5 g | 4,6 g |
| Utilis | Panama, Costa Rica | 51,0 g | 3,7 g |
| Rama | Nicaragua | 30,7 g | 2,1 g |
| Tigre | Peru | 63,5 g | 5,6 g |
| | | Macrocarpal | |
| Vaupés | Colombia | 138,8 g | 8,8 g |
| Putumayo | Colombia, Brazil, Ecuador | 110,7 g | 3,06 g |

The chemical composition of fruits reveals strong variation in carbohydrate and fat / oil content.

The starch content of fruits can be very high, and thus starch production by *B. gasipaes* potentially in the Amazon basin is high, ranging from 3.0 to 3.8 t per ha and year. This is considerably higher than starch production by maize in Amazonia which is less than 1 t per ha and year.

**Table 2:** Chemical composition of fruits of *Bactris gasipaes* (Examples taken from Clement and Arkcoll 1991)

| Region | Water | Protein | Oil | Carbo-hydrate | Fibres | Ashes |
|---|---|---|---|---|---|---|
| | % of fresh weight | % of dry matter | | | | |
| Amazon | 55.3 | 6.6 | 23.2 | 46.0 | 13.7 | 2.3 |
| Central America | 51.6 | 6.0 | 9.5 | 78.7 | 4.6 | 1.8 |

The experimental area of the SHIFT-polyculture experiment is characterized by an annual mean temperature of 27.2° C (Walter, 1975), precipitation of more than 1700 mm per year. The soils are ferralsols with a very poor cation-exchange-capacity. The soil contents of plant available minerals are very low (Klinge, 1975), the soil pH is low, between pH 3.5 and 4.9.

Fast growing and high biomass producing plants like *B. gasipaes* need to incorporate high amounts of mineral elements in the plant tissue. Efficient uptake by the root systems of minerals from soil solutions is dependent on root mass, the root distribution and physiological root parameters. The roots of *B. gasipaes* do not differentiate root hairs. It is assumed that other mechanisms and qualities of the root system guarantee an effective and successful uptake of minerals.

Root distribution, root architecture and growth dynamics of *B. gasipaes* are under study. This study presents preliminary data on root morphology, histology, and root anatomy.

## MATERIAL AND METHODS

The roots were taken from six to 6 to 9-month-old seedlings grown from seeds of a spineless *B. gasipaes* genotype and in some cases from the respective mother plants.

Germination was carried out in humid chambers in a peat-sand mixture of 3:1 (vol:vol), at 30° C, 80% r.H. and 11 hrs of light (Osram LW 58 w/25, 40 cm distance). After 57 days first seeds produced roots; between 6.7 and 28.7% of seeds germinated.

Seedlings were cultivated in a peat-sand mixture 3:2 (vol:vol) in plastic pots of 12 cm diameter at 23° C in a greenhouse under a 12 hrs day. Plants were watered twice daily, two times per week 1.5 g/l HaKaPhos fertilizer solution was applied.

### Preparation for light microscopy

Roots were washed with tap water, purified from soil residues and prepared in a fixation process. Roots were fixed in FAA 50%, cleared by sodium hypoclorite 20%, washed in distilled water and dehydrated in an alcohol series, of eight steps from 30% to 100% of ethanol, followed by transfer to xylole, and finally embedded in glycerine-gelatine according to Kaiser (Gerlach 1984). FAA consisted of 5 ml formaldehyde, 5 ml ethanol (96 %), 56 ml acetic acid, 34 ml deionised water. Staining with fuchsin or aniline-blue took place for 5' each at the 40% ethanol step.

For cuttings either a Vibratome (Series 1000 Sectioning System, Technical Products Inc.) or a Spencer microtome was used.

**Preparation for Scanning Electron Microscopy (SEM)**

The Preparation for Scanning Electron Microscopy (SEM) was done with Critical Point Drying and gold sputtering.

Freshly prepared root specimen of 3 to 5 mm in length were placed in metal baskets and fixed in FAA, 24 hrs, according to Gerstenberger and Leins (1978). After this first steps samples were rinsed 2 times in FAA for 15 min, then the specimen were dehydrated in formaldehyde-dimethylacetate and prepared for critical point drying in a Balzers CPD 030.

Samples were rinsed at 10° C with liquid CO2, and cooled down to 0°c; when the chamber pressure reached 50 bar, the CO2 was heated to 45° C. Consequently the pressure rises, the critical point was surpassed and the sample chamber was allowed to slowly equilibrate in pressure.

The dried samples were mounted on aluminium supports with glue, dried in a dessicator and sputtered with gold in a Balzers Sputter Coater SCD 050.

**SEM-studies**

SEM-studies were carried out using a Zeiss DSM 940 at 5 kV and a working distance of 11 to 14 cm.

**Documentation**

Photos were taken with an Olympus BH 2 using Kodak ASA 100.

## RESULTS

**Root system**

All roots of first order form second order roots. Some of the second order roots do not form third order rootlets, but most of them do. No fourth order roots have been found in undisturbed root systems. Roots system branching follows the herringbone-pattern. Roots of different orders reveal different diameters (Table 3), the diameter of the individual roots remains constant over the root length. Up to 20 % of the second order roots remain very short, are bulbous at their basis (Figure 2). The distribution of these stunted roots does not follow any constant pattern. The presumably are pneumatodes or pneumatorhiza (Tomlinson 1961, Velasco 1993).

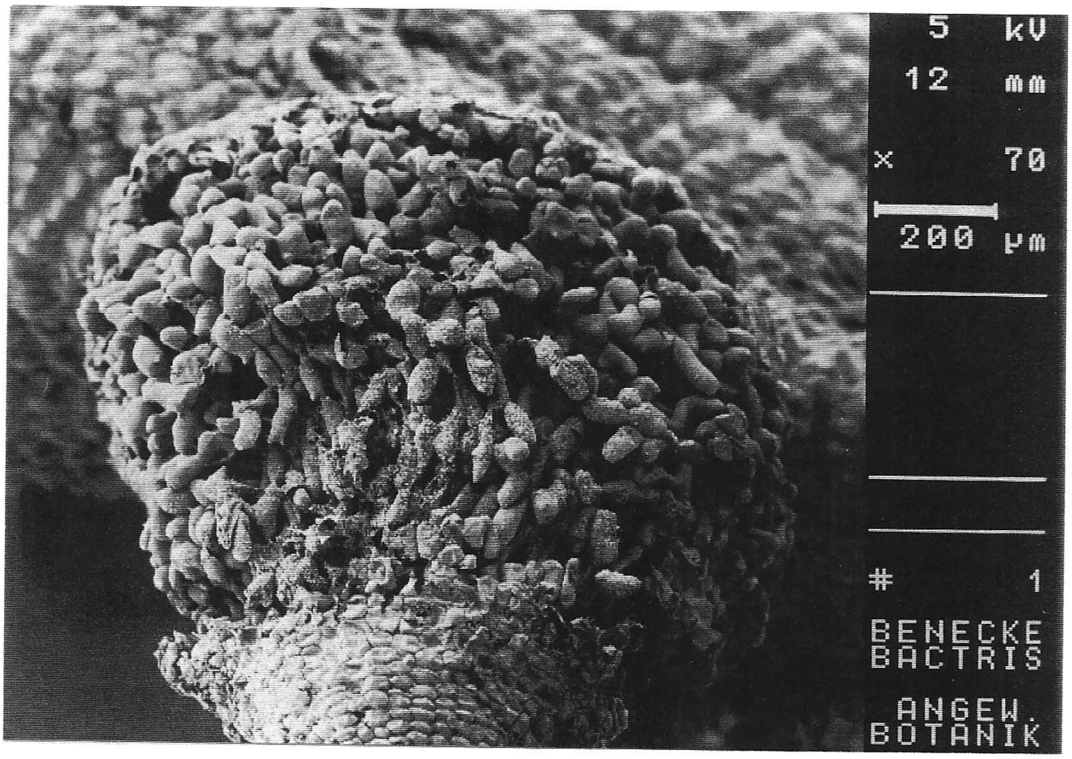


**Figure 2:** Stunted side roots of second order. The rhizodermis is obviously ruptured. The outer root cells form a spongy layer of rod- or citrus shaped cells with large intercellular spaces.

**Table 3:** Root radius and root surface areas.

| Order | $R_{ec}$ [ µm ] | $R_r$ [ mm ] | $A_{Bg}$ [ $mm^2$ ] | $A_c$ [ $mm^2$ ] |
|---|---|---|---|---|
| 1. | 33,77 ± 4,92 | 2,97 ± 0,33 | 891,30 ± 161,04 | 186,95 ± 33,18 |
| 2. a) | 35,01 ± 7,87 | 0,64 ± 0,04 | 183,32 ± 1,24 | 40,15 ± 0,25 |
| 2. b) | 29,92 ± 4,76 | 0,17 ± 0,01 | 43,44 ± 1,60 | 10,93 ± 0,65 |
| 3. | 30,83 ± 5,30 | 0,23 ± 0,03 | 59,40 ± 0,88 | 14,27 ± 0,17 |

Radius of the endodermis cells $R_{ec}$ , radius of the root $R_r$ , surface area of a root of *Bactris gasipaes* $A_{BG}$ , area of a cylinder with the same radius $A_c$

**Root anatomy**

The cortex consists of various cell types.

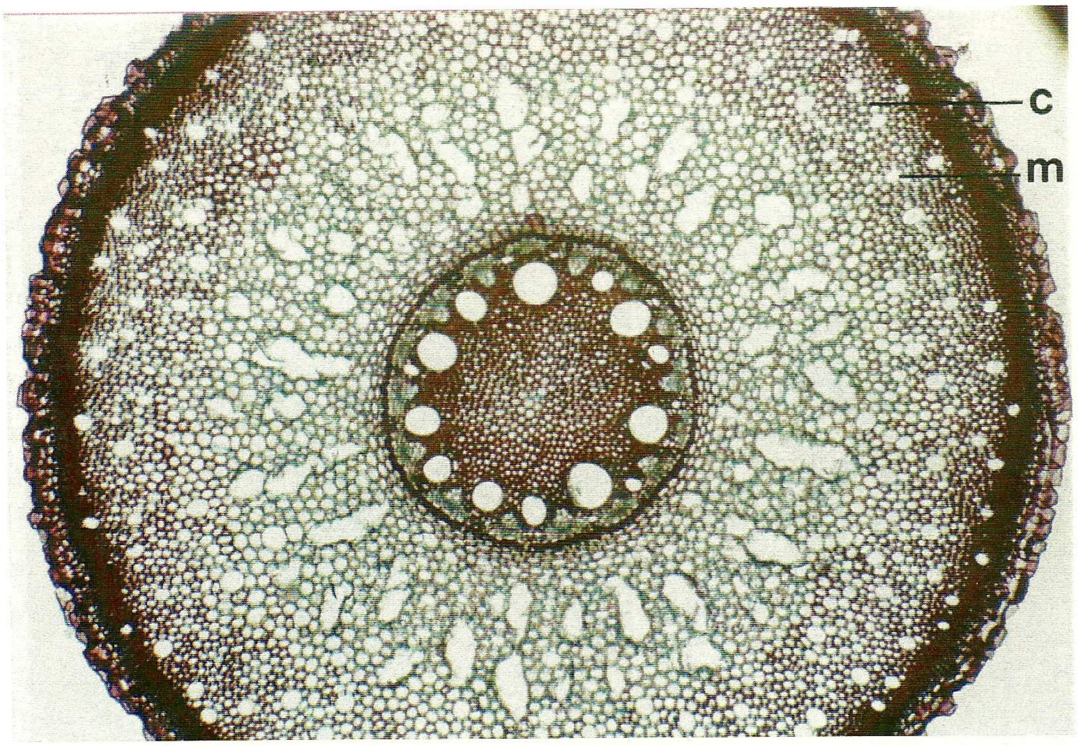


**Figure 3:** Cross section through a first order root of a mature *Bactris gasipaes* palm. cortex (c) cells, mucilage channels (m).

Like in many other monocotyledonous plants some compact cell layers surround the endodermis as the inner part of the cortex. One characteristic of many palm roots are fibers and mucilage channels. The mucilage channels are present as schizolysigenic cavities with thin cell walls in the middle part of the cortex. The endodermis consists of small and long cells with U-shaped wall thickenings. Casparian stripes in a primary developmental step are seen.

Passage cells are not characteristic for palm roots, but can be found in *Bactris* roots (Figure 4, 5).

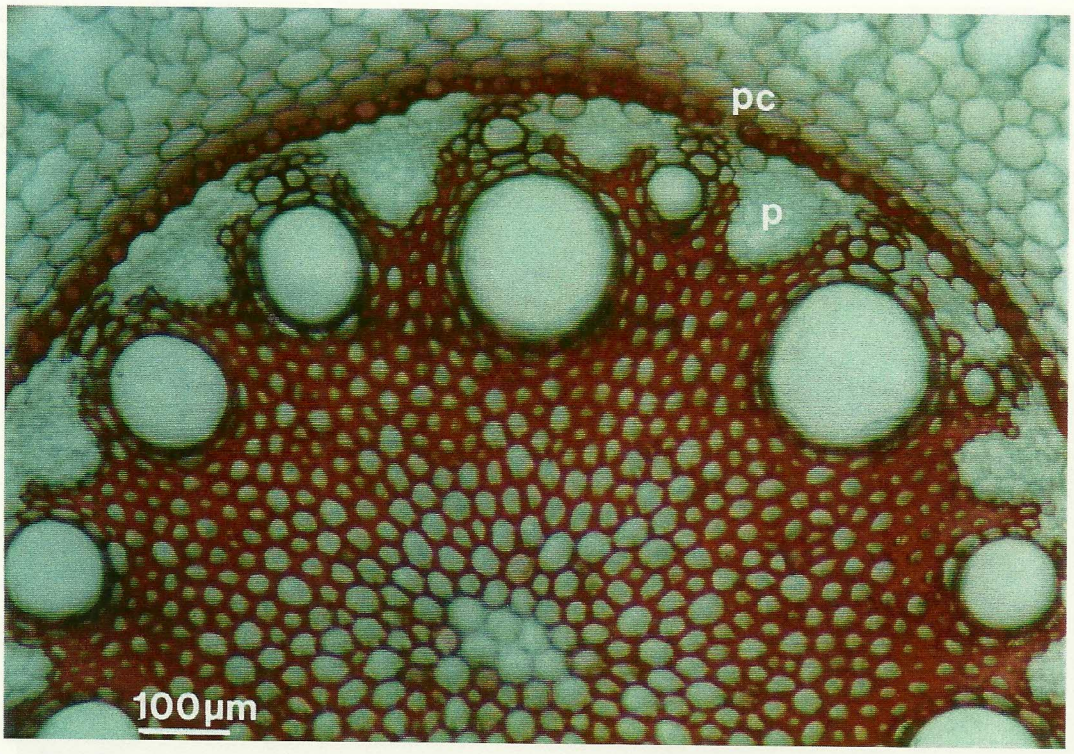


**Figure 4:** Transversal cutting of *Bactris* root. phloem (p), passage cell (pc).

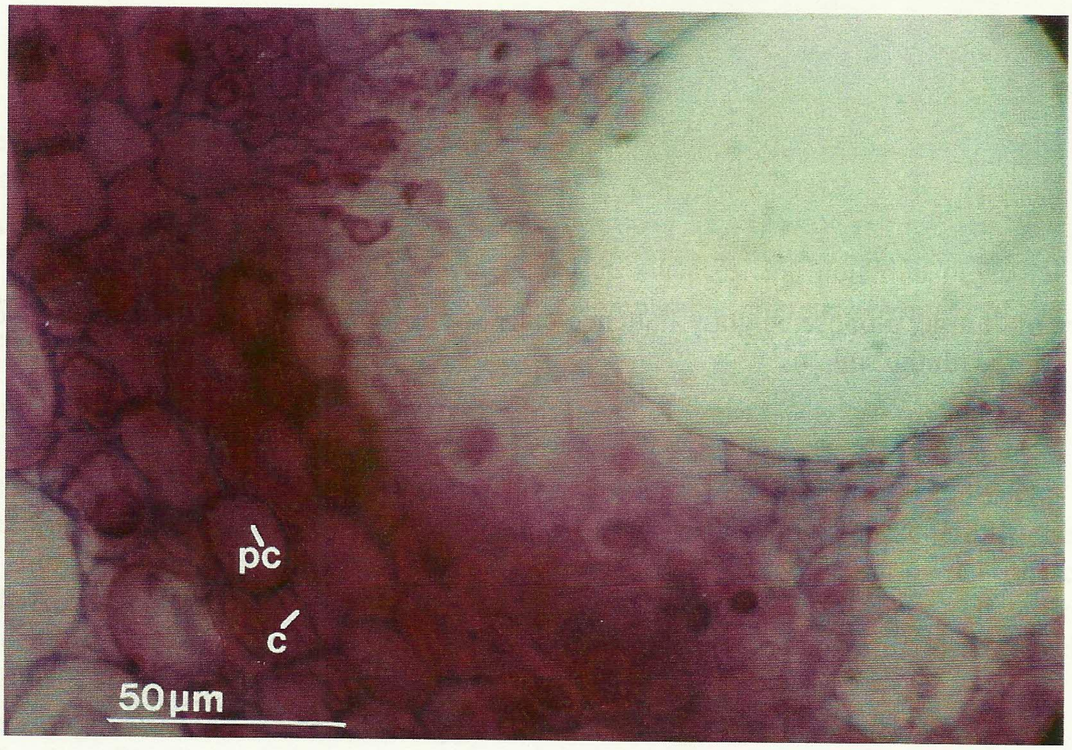


**Figure 5:** Endodermis with Casparian stripe (c) and passage cell (pc).

The outer most cortex layer is formed of 5 to ten cell layers of small, longitudinally stretched cells of about 10 µm in diameter. The isodiametric hypodermic cells are longitudinally oriented, thin walled and 30 to 50 µm in diameter. The exodermis layer is formed of globose, large, slightly flattened cells (Figure 6) of up to 10 µm in diameter. These cells are positioned in a spiral around the root cylinder. In scanning electron microscopic images the root surface resembles a corn cob (Figure 7). Under dry conditions these cells flatten and leave small cavities free.

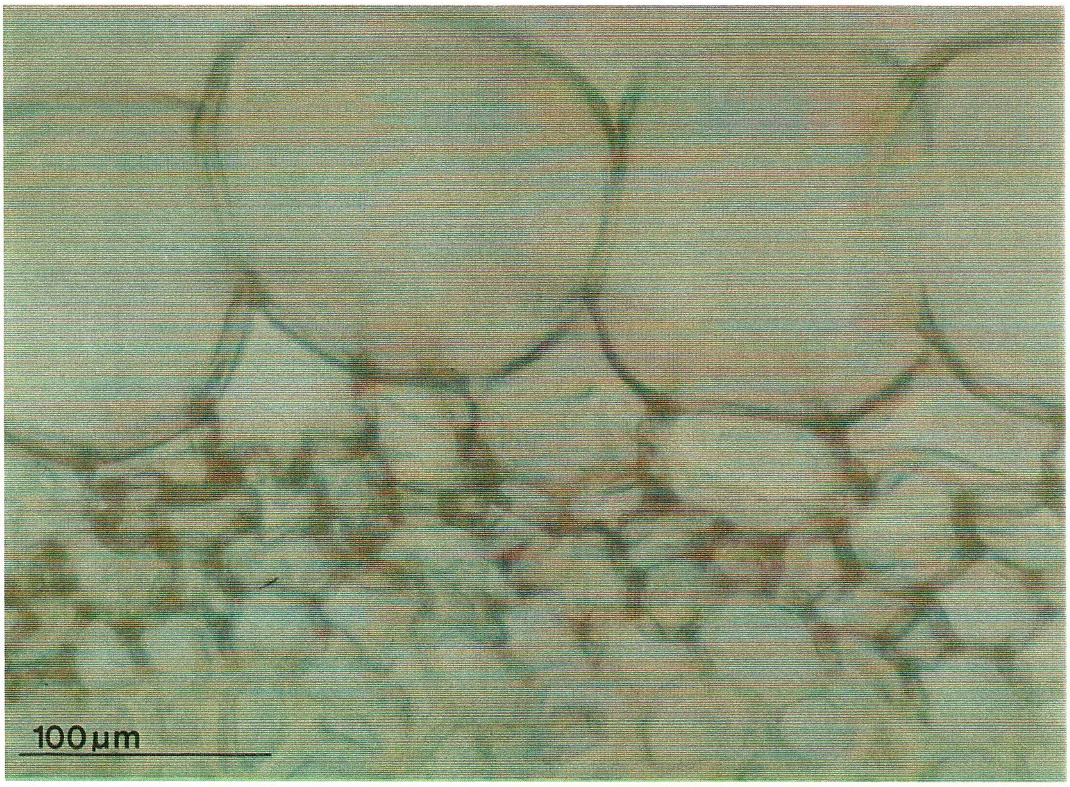


**Figure 6:** Large, globose, slightly flattened cells are forming the contact surface of the root with the soil.

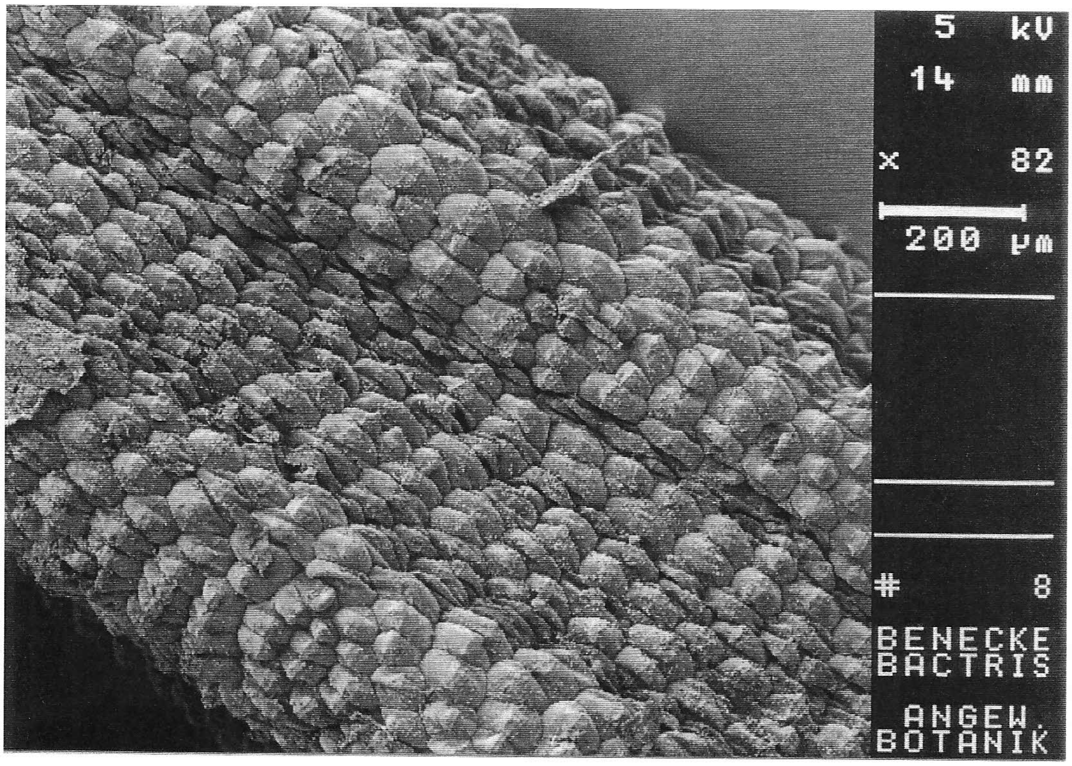


**Figure 7:** Scanning electron microscope image of a typical *Bactris* root surface revealing the corn- cob like structure.

The large root exodermis surface formed by these exodermis cells possibly are a functional equivalent to root hairs zones.

Based on the assumption that the exodermis cells are not fixed to one another by rigid cell walls but, instead, are flexible and provide free cell surfaces, the potential physiologically active root surface is 2 to 34 times larger than a comparable reference cylinder of the same diameter.

## DISCUSSION

The outermost layer of *Bactris* roots has been termed exodermis in this study. This term has been used because the outermost cell layer is found on the entire root length. It does not form any root hairs. In *Iris germanica* the young roots are covered by an one-celled rhizoderm, which is homologues to the epidermis. In elder roots the outer cell layers are formed by exodermal cell layers. The formation and the function of a bi- or multicellular exodermis is so far not completely understood.

According to Peterson (1998) the typical exodermal cell is characterized by cell wall modifications like the apposition or incrustation of suberin or lignin. In the structure, the exodermis may form structures similar to the endodermis (Enstone and Peterson 1997) and it may be uniform or dimorphic.

In the case of *B. gasipaes* roots the origin and development outmost cell layers have to be studies in detail in order to differentiate between "rhizodermis" and "exodermis".

In functional aspects the large volumed cells are also not fully understood. They do not reveal suberinized or lignified cell walls. The thin walled cells possibly give rise to large contact zones between the roots and the soil water solution.

Interestingly just recently Jourdan and Rey (1997) presented studies on oil palm roots (*Elaeis guineensis*), which also revealed a similar maize cob like structure like presented here for *B. gasipaes*.

Both species are typical vegetation components of the humid tropics and both are known to reveal a broad ecological amplitude.

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