Observations on the root system of the pejibaye palm (**Bactris gasipaes** H.B.K.) in Costa Rica*[1/]

JOHN VANDERMEER**

C O M P E N D I O

El sistema radical del pejibaye (Bactris gasipaes) *consiste de primero, una red extensiva superficial, que se extiende hasta cuatro y cinco metros del árbol, y segundo, una masa radical que se extiende por lo menos dos metros debajo de la superficie*

Introduction

IT is a commonly recurring theme that the future design of tropical agroecosystems should incorporate, in so far as possible, the structural complexities of undisturbed ecosystems (2, 3, 6, 16). Traditional agriculture commonly approaches such structural complexity, and it is normal for many tropical crops to be planted in the undestory of larger wtrees (e.g. coffee, cacao). It is likely that underplanting in plantations of tree crops will be an increasingly common occurrence in the near future.

The pejibaye palm, *(Bactris gasipaes* H.B.K.), so common in Costa Rica and Panamá, has seen relatively small exposure in the international literature (5, 7, 9, 10, 11, 12, 14, 15). It has recently been included in a prestigious survey of underexploited tropical crops with promising economic value (13). Despite a relative paucity of agronomic attention to this species, its popularity in Costa Rica suggests that it may come into increasing usage as an overstory crop in complex multicroping systems,

To my knowledge nothing has yet appeared in the literature regarding the root system of the pejibaye palm. If this species is to be used as an overstory in multicroping systems, it would be of critical importance to know something of its root system, both to suggest the influence of root competition on yields of particular planting patterns and also to suggest tillage programs which do not destroy significant portions of the overstory root system. Such knowledge is of special importance in light of the recent discovery of the heavy dependence of this species on a mycorrhizal association (8). To this end, the following observations are offered as a minimal description of the nature and extent of the pejibaye root system.

Study site

This study was undertaken in two pejibaye plantations at the La Selva field station, owned and operated by the Organization for Tropical Studies. The plantations were planted in the early 1960's but have not been systematically harvested since at least 1968. The undergrowth has been cleared periodically since their establishment. The first plantation (in which the surface samples were taken) is a combination of pejibaye and laurel *(Cordia alliodora)*. The pejibaye are planted in rows 10 m apart, at 5 m spacing within rows. The second plantation (in which the single tree was excavated) is a combination of pejibaye, cacao, and laurel. Rows of pejibaye and laurel alternate with rows of cacao. All rows are 4 m apart, the within row spacing of pejibaye being 8 m.

Surface roots were sampled with a core soil sampler 7 cm in diameter and 20 cm long. The soil plugs were thoroughly washed and the remaining root material dried in a plant dryer. Pejibaye roots, easily distinguished from other roots in the area, were separated from other material and weighed to the nearest 0,01 g. Samples were taken at 20 cm intervals from the base of four individual pejibaye trees. Basic measurements of these four trees are given in Table 1. All trees were on the edge of the grove and the sampling was done on a line leading away from the grove.

Additionally, a single tree was excavated to a depth of 2 m. A trench was dug from the base of the tree to a distance of 1.5 m away from the tree. Samples were taken with the core sampler at 20 cm intervals from the surface down at three different points, first directly

* Received for publication June 21st. 1977

1/ This research was supported by a Rackham faculty research grant from the University of Michigan. The field work was assisted by Cathy Bach, Charlotte Boucher, Diane DeSteven, Sandra Limrick, and Jean Stout

** Department of Ecology and Evolutionary Biology, University of Michigan, Ann Arbor, Michigan 48104, U.S.A.

Table 1 —Characteristics of the trees for which surface samples were made.

Tree number	Number of stems	Height of tallest stem (m)	Height of next tallest stem (m)
A	1	3.5	—
B	4	14.0	11.5
C	1	5.5	—
D	5	14.9	9.9

beneath the surface root mass of the tree, second 0.6 m away from the tree, and third 1.2 m away from the tree. The central root mass exposed in this excavation is shown in Figure 1.

Fig. 1 —*Photograph of the central root mass of the excavated tree*

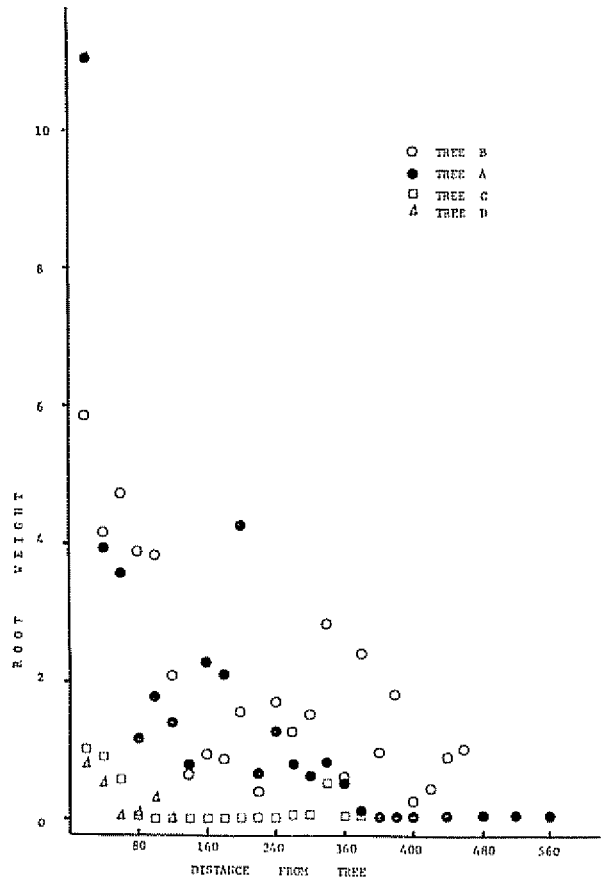

Fig. 2 —*Weight of root material (in gm/38 ml of soil material) as a function of distance from parent tree for the four trees from which surface root samples were taken*

Results

In Figure 2, the weight of pejibaye root material has been plotted (in g/38 ml) a a function of distance from parent tree for the four trees from which surface root samples were taken. There is clearly a rapid decline in amount of root material as one moves away from parent tree, and that decline is, of course, greater for the larger trees. It is critical to note that the extent of the canopy of the small trees is about one meter (*i.e.* a canopy diameter of about 2m) while that of the large trees is about 1.5 meters (*i.e.* a canopy diameter of about 3 meters). Figure 2, then illustrates an extremely important point. Although the popular rule of thumb that the extent of a tree's system is roughly equivalent to the extent of its canopy may be justly assumed in the case of the two smaller trees, that rule breaks down completely when applied to the two larger trees. Indeed, according to these data approximately 75 per cent of all surface roots are to be found outside of the ground perimeter defined by the edge of the canopy (about 50 per cent of all roots are further than 1.5 m along a straight line away from the tree).

Table 2.—Summary statistics for regression analyses (see text for explanation).

Description	Decay rate	Signif cance of regression	R^2	Error degrees of freedom
Surface roots	0.0031	0 001	0 58	45
Depth under tree	0.0204	0 001	0 92	8
Depth at 0 6 m	0.00037	n s.	0 00	6
Depth at 1.2 m	0.0045	0 05	0 52	6

The relationship between the density of surface roots and distance from parent treen can be approximately described by the exponential equation, $y = Ae \exp{-bx}$ where y is the weight of pejibaye roots at a distance of x centimeters from the tree, b is the "decay" constant, and A is a constant from which one may calculate the density of roots directly at the base of the tree. Fitting the data from the two large trees in Figure 1 to the above equation (i.e. the natural log of one plus the weight of pejibaye roots, regressed against distance from the parent), a significant relationship was found, as shown in the first row of Table 2.

Table 3.—Distribution of roots in excavated tree. First column is for samples taken directly beneath the tree. Second column is for samples taken 0.6 m away from tree. Third column is for samples taken 1.2 m away from tree. Each of the three groups of samples were taken by beginning at the surface of the ground and sampling every 20 cm downward. Figures are grams of roots per 38 cc of soil.

Depth (cm)	Location		
	Beneath tree	0 6 from tree	1 2 from tree
0	110.56	0.91	1 32
20	29.02	1 77	0 37
40	42.50	0 00	0 00
60	11.00	0 54	0 01
80	12.51	0 22	0 00
100	6.63	1 02	0 00
120	5.93	0 00	0 00
140	1.40	2 31	0 00
160	2.22		
180	1.29		

The distribution of roots as a function of depth is indicated by the data in Table 3. A strong decrease in root density is indicated for the position directly beneath the tree, but less of a relationship with depth is found for the 0 6 m and 1 2 m positions. Regressions were performed on these data with natural log of one plus the pejibaye root density regressed against depth. The results are given in rows 2, 3 and 4 of Table 2. Indeed the relationship between root density and depth is very dramatic directly under the tree (roughly speaking, 92 per cent of the variance in root density is cent accounted for depth alone as opposed to 58 per cent accounted for by distance from tree; see column 3 of Table 2). But that relationship weakens quickly as one moves away from the tree.

In Figure 3, the logs of the root weights were plotted against the depths for all three positions (beneath the tree, 0.6 m away, and 1.2 m away), and the log of root weights against distance from parent tree for the previously described surface samples. Also in Figure 3 is plotted the various regression lines which were summarized in Table 2.

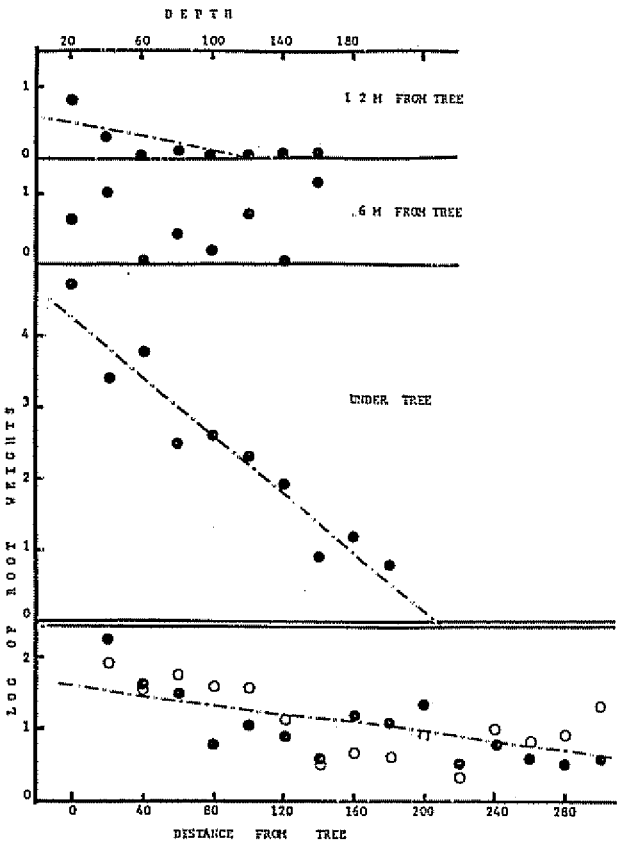

Fig. 3.—*The distribution of roots as a function of depth. Top three graphs are from the excavated tree (top graph represents a distance of 1.2 m from the tree, second graph a distance of 0 6 m and third graph directly under the tree), and the bottom graph is a log plot of the data from Figure 2, presented here for comparative purposes.*

Discussion

Is is clear that there is an approximately logarithmic relationship between surface root density and distance from tree For a full grown tree this relationstance fro mtree For a full grown tree this relationship implies that approximately 75 of all surface root material is found outside of the ground perimeter defined by the edge of the canopy Such an ob·ervation suggest that there may be important limitations on the extent of tillage allowable under a pejibaye plantation For example, if all land in a plantation is disc tilled, except for that land within the crown perimeters of the individual trees, approximately 75 per cent of the surface root system of the whole plantation will be destroyed Lacking quantitative data on actual root function, it is impossible to state exactly what might be the effects of such major destruction, but it seems safe to speculate that those effects may be manifest in critical reductions in production

Although casual observation of fallen pejibaye trees may give one the impression that the entire root system is very superficial, the excavation clearly indicates that there is a substantial root mass which extends at least to a depth of two meters (see Figures 1 and 3) Further away from the tree the system does indeed appear to be superficial

All of the above leads one to the general impression that the root system as a whole consists of first, an extensive surface network, extending four or five meters away from the tree, and second, a deep core of root mass extending at least 2 m below the surface

Literature cited

1 ANDERSON, E and WILLIAMS, L O Maize and sorghum as a mixed crop in Honduras. Annals of the Missouri Botanical Garden 41 (2): 213 215 1954

2 CLARKE, W. C. Maintenance of agriculture and human habitats within the tropical forest ecosystem Human Ecology 4(3):247-259 1976

3. DICKINSON, J C. Alternatives to monoculture in the humid tropics of Latin America Professional Geographer 24: 217-222. 1972

4 HARRIS, D R The origin of agriculture in the tropics American Scientist 60:180-193. 1972.

5. HEISER, C B. and LEON, J The pejibaye *(Guilielma gasipaes)* Nature Magazine 48: 131-132 1955

6 HOLDRIDGE, L R Ecological indications of the need for a new approach to tropical land use Economic Botany 13(4): 271-280 1959.

7 HUNTER, J R The lack of acceptance of the pejibaye palm and a relative comparison of its productivity to that of maize Economic Botany 23:237-244. 1969

8. JANOS, D P Vesicular-Arbuscular mycorrhizae affect the growth of *Bactris gasipaes* H.B.K. Principes (to be published in 1977)

9 JOHANNESSEN, C. L Pejibaye palm: yields, prices and labor costs. Economic Botany 20 (3): 302-315. 1966

10 ———— Pejibaye in commercial production Turrialba 16(2): 181-187. 1966

11 ———— The domestication process in trees reproduced by seed: the pajibaye palm in Costa Rica Geographical Review 56(3): 363-376 1966

12 ————. Pejibaye palm: physical and chemical analysis of the fruit. Economic Botany 21(4): 371-378 1967

13. NATIONAL ACADEMY OF SCIENCES Underexploited tropical plants with promising economic value Report of an Ad Hoc Panel of the Advisory committee on Technology Innovation, Board on Science and Technology for International Development. 1975. 186 p

14 POPENOE, W and JIMENEZ, O. The pejibaye, a neglected food plant of tropical America. Journal of Heredity 12(4): 151-166 1921

15. SEIBERT, R J The importance of palms to Latin America: pejibaye a notable example Ceiba (Honduras) 1(2): 65-74 1950

16 TOSI, J. A and VOERTMAN, R F Some environmental factors in the economic development of the tropics Economic Geography 40: 189-205 1964.