Sloanea berteriana Choisy Motillo

Elaeocarpaceae Elaeocarpus family

SO-ITF-SM-84
September 1997

Peter L. Weaver

Sloanea berteriana Choisy, called motillo in Puerto Rico, cacao cimarron in the Dominican Republic, and petit coco or chataignier in Guadeloupe and Martinique, is an evergreen tree that reaches 30 m in height and 60 to 90 cm in d.b.h. at maturity. Buttresses at the base of the trunk (fig. 1), especially in large trees, aid in field identification of motillo. Another useful diagnostic characteristic is that the leaf petiole is swollen at each end (*45*). Motillo wood is heavy, and the main uses of this species have been for fenceposts and construction.

Figure 1.—*Motillo (*Sloanea berteriana *Choisy) in a drainage area of the Luquillo Mountains of Puerto Rico. Note buttresses and large leaves.*

Peter L. Weaver is a research forester at the International Institute of Tropical Forestry, U. S. Department of Agriculture, Forest Service, Río Piedras, PR 00928-2500, in cooperation with the University of Puerto Rico, Río Piedras, PR 00936-4984.

HABITAT

Native Range

Motillo is endemic to the Caribbean Islands (fig. 2), growing naturally in Hispaniola (*2, 30, 37*), in Puerto Rico (*31*), and in the Lesser Antilles from St. Kitts (*5*) through Guadeloupe (*22*) and Dominica (*5*) to Martinique (*48*). Recent taxonomical studies, however, indicate that this species may no longer exist on Martinique (*22*).

Motillo is a common component of the montane forests of Puerto Rico's Luquillo Mountains at elevations of 150 to 600 m (*50, 54, 55*). Before 1900 in Puerto Rico, this species was also common in the Cordillera Central at elevations of 150 to 900 m (*50*). Much of the Cordillera Central, however, is now covered by secondary forest where motillo is less common (*6, 7*).

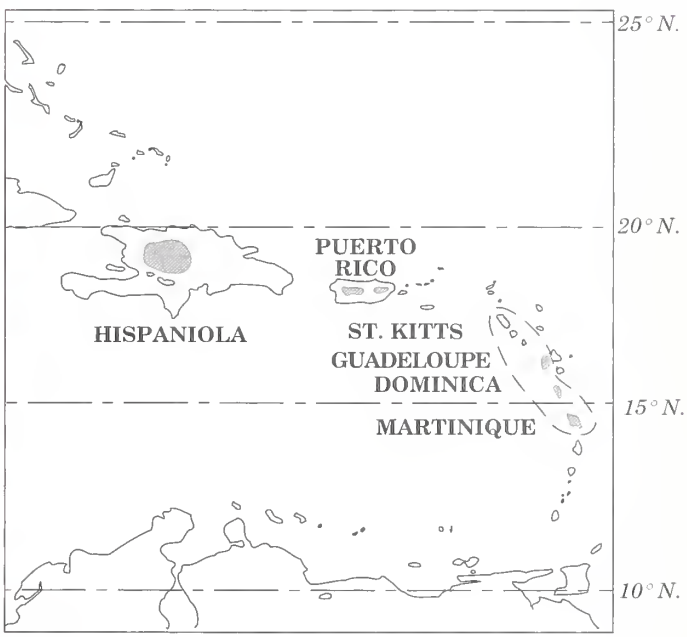

Figure 2.—*Shaded areas represent the native range of motillo (*Sloanea berteriana *Choisy) in the Caribbean: Hispaniola, Puerto Rico, and from St. Kitts to Martinique.*

Climate

In Puerto Rico, motillo grows in moist to wet montane forests. Rainfall in these forest types ranges from 1800 to 4000 mm/yr, with mean annual temperatures of 20 to 24 °C (*10*). Rainfall throughout the range of this species is similar to that of Puerto Rico, although in some areas of Dominica (*26*), rainfall exceeds 5000 mm/yr. The areas to which motillo is native are frost-free.

Soils and Topography

Motillo in the lower montane rain forest of Dominica grows in heavy red clay soils underlain in several areas by impervious hardpans (*26*). These poorly drained soils are low in oxygen.

In the Luquillo Mountains of Puerto Rico, motillo grows mainly on acid clay soils classified as Ultisols and Inceptisols. This species is found on all topographic positions but is most common on steep slopes, on lower slopes and bottomlands (*16*), or in moist ravines (*31*). Soils in these lower slope positions are characterized by higher levels of magnesium (*28*). In the Bisley watershed of the Luquillo Mountains, motillo trees and saplings are most common in lower topographic positions or valleys (*3*).

Associated Forest Cover

The most magnificent forest of the Caribbean Archipelago is the rain forest designated as the *Dacryodes-Sloanea* association (*48*). *Dacryodes excelsa* Vahl., the major component of this forest, ranges from Puerto Rico through Grenada. The *Sloanea* component of the association is composed of several tree species, including motillo. Table 1 shows the tree species most commonly associated with motillo in Caribbean forests.

In Puerto Rico, motillo is largely confined to the lower montane rain forest (sensu Beard; *5*), which is the equivalent of the tabonuco forest (*51*), or roughly the equivalent of the subtropical wet forest and subtropical rain forest (sensu Holdridge; *21, 27*). It is far less common in the montane rain forest (sensu Beard; *5*), which is the equivalent of the colorado forest (*51*), or roughly the equivalent of the lower montane wet forest and lower montane rain forest (sensu Holdridge; *27*). Motillo also exists in the more humid areas of subtropical moist forest.

Surveys of all trees ≥10.0 cm in d.b.h. during the mid-1940's showed that motillo constituted 4.2 percent of all stems in the tabonuco forest but only 0.6 percent of the stems in the colorado forest (*51*). Of the 30 principal tree species in the tabonuco forest, motillo ranked third in stem density and ninth in both basal area dominance and volume (*9*). Most of the stems were in d.b.h. classes of less than 30 cm. In the tabonuco forest of the Bisley watershed, motillo averaged 25 t/ha, or about 11 percent of the aboveground biomass (*44*).

In contrast, motillo is uncommon in Puerto Rico's secondary forests. In the islandwide survey of 1980, which covered one-half of Puerto Rico, motillo comprised 2,500 m^3 of the sawtimber volume, or only 0.5 percent of the total volume sampled (*7*). In a 1983 survey of the Toro Negro forest in the Cordillera Central, motillo, with only 0.3 percent of the stems and 1.2 percent of the basal area, constituted a relatively minor portion of the mixed sample of primary and secondary stands (*6*).

Table 1.— *Tree species most commonly associated with motillo (*Sloanea berteriana *Choisy) at various locations in Caribbean forests*

Country	Location	Elevation	Rainfall	Principal associated species	Source
		- - Meters - -	*mm/yr*		
Dominica	Layou Valley	275-425	~4000	*Dacryodes excelsa* *Sloanea truncata* *Sterculia caribaea*	(*5*)
	Sylvania	~500	5000	*Amanoa caribaea* *D. excelsa* *Tapura antillana*	(*26*)
Puerto Rico	Bisley	300	3300	*D. excelsa* *Guarea guidonia* *Inga fagifolia* *Prestoea montana* *	(*3*)
	Luquillo Mountains, Rio Grande Sabana 4 Sabana 8	180-600	2300 to 3500	*Cecropia peltata* *D. excelsa* *Ormosia krugii* *P. montana*	(*16*)
	Luquillo Mountains, tabonuco forest	250-600	3000	*C. peltata* *D. excelsa* *Euterpe globosa* * *Micropholis garciniaefolia*	(*51*)
St. Kitts	Wingfield Estate	275-450	~3000	*Aniba bracteata* *D. excelsa* *E. globosa*	(*5*)

**Euterpe globosa* is an earlier name for *Prestoea montana*.

LIFE HISTORY

Reproduction and Early Growth

Flowering and Fruiting.—Flowers of motillo are borne on unbranched racemes 5 cm or less in length, with several flowers emerging on fine, hairy stalks about 1.3 to 1.9 cm in length (*31*). Each flower contains four or five pale yellow, pointed, hairy sepals about 0.6 to 0.8 cm long. Petals are absent. Numerous hairy stamens 0.6 cm or less in length are attached on a broad disk. The hairy pistil, 0.6 cm long, consists of a four-celled ovary, a style, and four stigmas (sometimes three-celled ovary and three stigmas). Flowering in Puerto Rico occurs mainly between February and July (*20*).

Seed Production and Dissemination.—Motillo seed capsules consist of four parts and are hard, having walls about 0.5 cm thick. The capsules contain a few rounded to elliptic seeds about 1.3 cm long (*31*). Fruit fall occurs in all months (*31*), with the main fruit fall coinciding with the winter season between November and March (*20, 38*).

In Puerto Rican studies conducted in the late 1940's, a sample of 1,125 green fruits weighed shortly after collection had an average of 110 fruits per kilogram; seeds, some with fruit parts attached, averaged 1,170 per kilogram (*34*). The moisture content of green fruits represented 42 percent of the total weight of the fruits (*34*). The germination for seeds sowed immediately into the soil was 17 percent (*34*). Seeds stored for 1 month at 5 °C did not germinate, but 45 percent of those stored at 26 °C for 1 month did germinate (*34*).

Recent Puerto Rican studies using a sample of 80 fruits and seeds confirmed earlier results: fruits averaged 9.04 ± 0.22 g in weight, and seeds averaged 0.46 ± 0.01 g (Alberto Rodriguez, personal communication[1]). A test using 250 motillo seeds stored a few days under ambient conditions had 52-percent germination beginning at 5 days and terminating after 9 days.

Seedling Development.—Motillo seedlings are hypogeal, but have been further classified as phanerocotyler, that is, characterized by seedlings escaping from the testa during germination (*18*). The initial growth of motillo is slow. Of 116 germinated seeds planted in plastic bags, 82 percent survived for 10 months while being exposed to direct sunlight. The 95 surviving seedlings grew to a mean height of only 12.5 ± 0.2 cm. Watering problems caused by Puerto Rico's prolonged drought in 1993-94 probably had a negative impact on seedling survival and development. Moreover, partial shading of seedlings or root innoculation with endotrophic mycorrhizae, or both practices combined, may have given different results.

Vegetative Reproduction.—No vegetative reproduction of motillo has been observed in undisturbed forests. After Hurricane Hugo, however, new stems sprouted along the length of standing or leaning trunks from which most of the crowns had been lost. Sprouting was also observed along the trunks of fallen trees.

Sapling and Pole Stage to Maturity

Growth and Yield.—The largest motillo in Puerto Rico measures 2.4 m in d.b.h. and 26.0 m in height and has a crown spread of 22.2 m (IITF files[2]). In general, however, motillo does not attain a large size in Puerto Rico.

Observations of tree growth are available from several permanent plots scattered throughout the tabonuco forest in the Luquillo Mountains. Measurements spanning 18 to 30 years showed mean annual d.b.h. growth of 0.30 to 0.69 cm/yr for trees ≥10 cm in d.b.h. and 0.09 to 0.18 cm/yr for trees ≥4 cm in d.b.h. (table 2). These growth rates are comparable to other tree species in the same forest type.

Table 2.—*Comparative growth data for motillo* (Sloanea berteriana *Choisy) in Puerto Rico*

Plot	Elevation	Trees sampled	Duration	D.b.h. growth	Source
	- - Meters - -	*Number*	*Years*	*cm/yr*	
Rio Grande	420-600	17	18	0.30 *	(*17*)
Sabana 4	210-600	41	18	0.48 †	(*17*)
Sabana 8	180-360	8	18	0.69 *	(*17*)
Tabonuco ridge 1	400	17	30	0.09 ‡	(*54*)
Tabonuco slope 3	570	14	30	0.10 ‡	(*54*)
Tabonuco thinned	450	3	30	0.18 §	(*54*)
Several plots	400-600	30	5	0.48 ¶	(*49*)

* Trees ≥10 cm in d.b.h., thinned plots.
† Trees ≥10 cm in d.b.h., undisturbed plot.
‡ Trees ≥4 cm in d.b.h, undisturbed plot.
§ Trees ≥4 cm in d.b.h., thinned plot.
¶ Codominant and intermediate trees from several plots within the Luquillo Mountains.

[1]Alberto Rodriguez, forest technician, International Institute of Tropical Forestry, P.O. Box 25000, Río Piedras, PR 00928-2500.

[2]Register of champion trees of Puerto Rico, International Institute of Tropical Forestry, P.O. Box 25000, Río Piedras, PR 00928-2500.

Rooting Habit.—Motillo seedlings 15 cm in height have taproots that average about 20 cm in length. Numerous lateral roots averaging 5 to 8 cm in length emerge along the length of the taproot. Motillo roots in natural conditions grow in association with endotrophic mycorrhizae (*19*). Root grafting between live trees and adjacent old stumps, which then remain alive, has been observed in the Luquillo Experimental Forest (*40*).

Reaction to Competition.—Motillo is classified as a primary forest species (*46*). This designation was derived by comparing the survival of seedlings and understory trees in a closed forest, the seed size, and the specific gravity of wood for species that reach the canopy in a tabonuco forest. Motillo's composite score, based on the high survival of seedlings and understory trees, the large seeds, and the dense wood of this species, resulted in a ranking of third most primary among the 29 species studied, after *Tetraqastris balsamifera* (Sw.) Kuntze, which ranked first, and *Eugenia stahlii* (Kiaersk) Krug & Urban, which ranked second (*46*) .

Data from four permanent plots in the tabonuco forest may provide insights into motillo's reaction to competition (table 3). In 1946, 14 years after the passage of Hurricane San Cipriano, motillo accounted for 6.0 percent of the stems and 2.7 percent of the basal area in the four stands combined. By 1976, motillo's proportion of stems and basal area had declined to 4.7 and 2.2 percent, respectively. About 54 percent of the motillo stems originally tallied in 1946 survived to 1976.

Motillo regenerated well after the 1932 hurricane (*15*) as witnessed by the subsequent increase in the number of small stems. The d.b.h. growth of motillo in thinned stands measured for 18 to 30 years was 48 percent greater than that on undisturbed control plots (*54*). Conditions immediately after hurricanes may be excellent for the germination and initial growth of motillo. Moreover, with adequate spacing, sustained d.b.h. increment is also possible. However, as the post-hurricane forest recovers, numerous small trees succumb, basal area increases, and the forest canopy closes. Under these conditions, motillo's proportions of both stems and basal area decline (table 3).

Ecological data on motillo are available from numerous studies conducted in the Luquillo Mountains. The average weight of 814 motillo leaves was 9.3 mg/cm^2 (*40*), that is, a specific leaf weight of 107.5 cm^2 /g. The number of stomata on the lower epidermis of motillo leaves averaged 40,000 per square centimeter(*14*). Stomate numbers were at the median for 30 species of measured plants, mainly trees. Stomate and pore sizes, however, tended to be somewhat less than the respective medians for 30 species.

Other studies show that fungal decomposition of motillo leaves in a rain forest stream was about 20 percent slower than that of other common canopy species in the tabonuco forest (*42*). In contrast, the disappearance of motillo leaf litter on the forest floor was the slowest of three primary species tested but more rapid than three secondary species (*12*). Other ecological studies of motillo provided information on biomass and nutrient content for plant components (*23, 24, 41, 44*), estimates of leaf chlorophyll content (*39*), various metabolic parameters related to seedling photosynthesis and respiration (*33*), and carbon values in the leaves, stems, and roots of seedlings (*36*).

Damaging Agents.—Motillo wood is moderately resistant to the drywood termite *Crypotermes brevis* Walker (*56*) but is not durable in the ground or resistant to marine borers (*32*).

Acanalonia aqilis and *Nipaecoccus nipae*, both homopteran insects, were collected on motillo foliage and may consume the leaves of this species (*35*). Moreover, an unidentified pathogen was responsible for killing portions of large motillo crowns (Frank H. Wadsworth, personal communication[3]).

Motillo trees in the Luquillo Mountains that had been

Table 3.— *Comparative data for motillo (*Sloanea berteriana *Choisy) in the Luquillo Mountains of Puerto Rico* *

Plot	Basal area				Number of stems				Survival
	1946		1976		1946		1976 †		of 1946
	Stand	Motillo	Stand	Motillo	Stand	Motillo	Stand	Motillo	motillo stems†
	Meters^2/hectare				*Number/hectare*				*Percent*
El Verde 3	20.6	1.67	25.0	1.67	1,728	285	1,410	119	32
Palm slope 2	31.9	0.65	31.8	0.82	1,772	51	1,470	59	51
Tabonuco ridge 1	43.7	1.00	51.1	0.31	1,778	82	1,188	52	51
Tabonuco slope 3	41.6	0.36	43.5	0.53	2,359	43	2,032	53	81
Mean	34.4	0.92	37.8	0.83	1,909	115	1,525	71	54

* Sources: *15, 34*

† The 1976 data set includes the ingrowth of motillo and other species between 1946 and 1976. The survival data refers only to the percentage of motillo stems tallied on the plots in 1946 that survived to 1976.

[2]Register of champion trees of Puerto Rico, International Institute of Tropical Forestry, P.O. Box 25000, Río Piedras, PR 00928-2500.

[3]Frank H. Wadsworth, research forester, International Institute of Tropical Forestry, P.O. Box 25000, Río Piedras, PR 00928-2500.

defoliated during Hurricane San Felipe in 1928 refoliated within 6 months (*4*). After Hurricane Hugo in 1989, motillo trees at El Verde, to the leeward of the storm in the Luquillo Mountains, suffered various impacts, including defoliation, branch loss, snapped trunks, and uprooted stems; some trees died (*53*).

SPECIAL USES

Motillo is a very hard, heavy, strong, multicolored wood (*32*) with a specific gravity of 0.8 g/cm^3 (*31, 40*). The heartwood may be grayish, grayish-yellow brown, yellowish brown, or uniform pinkish brown to chocolate brown. The heartwood is usually distinguishable from the yellowish sapwood.

Motillo wood air-seasons moderately well with a moderate amount of degrade. A slight to moderate amount of warp, surface checking, and uniform shrinkage occurs during seasoning. This wood works fairly well and yields good to excellent surfaces in all machining operations but takes screws and nails poorly.

The wood of motillo trees has medium texture, low luster, and irregular grain and is not particularly attractive; as a result, this wood has been used sparingly for furniture and cabinets (*31, 32*). Motillo wood is mainly used for crossties, construction, boat parts, heavy duty flooring, handles, farm implement parts, and pilings in areas free of marine borers (*31, 32, 52*). Preservative treatments in 5-percent pentachlorophenol[4] dissolved in diesel oil, as well as a double diffusion process using sodium fluoride followed by copper sulfate, increased the service life of fenceposts in Puerto Rico by about 10 years (*13*).

The Puerto Rican parrot, *Amazona vittata*, feeds on motillo seeds in the Luquillo Forest (*47*). In the Dominican Republic and Dominica, large specimens of *Sloanea*, possibly motillo, serve as parrot nesting sites (*47*). In Puerto Rico, however, motillo rarely grows large enough to produce good nest cavities.

GENETICS

The nuclear volume of motillo (*29*) and the content of deoxyribonucleic acid in sun and shade leaves of this species in the Luquillo Mountains (*11*) have been reported. *Rheedia laterifolia* Bert. ex Choisy non L. is reported as a synonym for motillo (*48*).

Another species, *S. amyqdalina* Griseb., rare in the Maricao Forest in western Puerto Rico, is also reported from Cuba and Hispaniola (*31*). Moreover, several other species of *Sloanea* grow in the Caribbean Archipelago from Cuba and Jamaica through the Lesser Antilles to Grenada (*1, 2, 5, 8, 30, 43, 49*). Many of these species are largely confined to the lower montane rain forest and are rarely found in other communities. Stehle (*44*) suggested that these species might be relicts of conservative endemism in separate insular rain forests, or possibly species subject to endemism after segregation from continental species. The genus *Sloanea*, the second largest in the family Elaeocarpaceae, contains about 120 tropical Asian and American tree species (*25*).

[4] Use of pentachlorophenol has been banned by the Environmental Protection Agency.

LITERATURE CITED

1. Adams, C.D.; Proctor, G.R.; Read, R.W. 1972. Flowering plants of Jamaica. Mona, Jamaica: University of the West Indies. 848 p.
2. Barker, Henry D.; Dardeau, William S. 1930. Flore D'Haiti. Port-Au-Prince, Haiti: La Direction du Service Technique du Departement de L'Agriculture et de L'Enseignement Professionnel. 455 p.
3. Basnet, Khadga. 1992. Effect of topography on the pattern of trees in the tabonuco (*Dacryodes excelsa*) dominated rain forest of Puerto Rico. Biotropica. 24(1): 31-42.
4. Bates, Charles Z. 1929. Efectos del huracán de 13 de septiembre de 1928 en distintos árboles. Revista de Agricultura de Porto Rico. 23: 113-117.
5. Beard, J.S. 1949. The natural vegetation of the Windward and Leeward Islands. Oxford Forestry Memoirs 21. Oxford, England: Clarendon Press. 192 p.
6. Birdsey, Richard A.; Jimenez, Diego. 1985. The forests of Toro Negro. Res. Pap. S0-222. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 29 p.
7. Birdsey, Richard A.; Weaver, Peter L. 1982. The forest resources of Puerto Rico. Res. Bull. S0-85. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 59 p.
8. Bisse, Johannes. 1981. Arboles de Cuba. Habana, Cuba: Ministerio de Cultura, Editorial Cientifico-Técnica. 384 p.
9. Briscoe, C.B.; Wadsworth, F.H. 1970. Stand structure and yield in the tabonuco forest of Puerto Rico. In: Odum, Howard T.; Pigeon, Robert F., eds. A tropical rain forest. Washington, DC: U.S. Atomic Energy Commission, Division of Technical Information: 79-89. Chapter B-6.
10. Calvesbert, Robert J. 1970. Climate of Puerto Rico and the U.S. Virgin Islands. Climatography of the United States 60-52. Silver Spring, MD: U.S. Department of Commerce, Environmental Science Administration, Environmental Data Service. 29 p.
11. Canoy, Michael J. 1970. Deoxyribonucleic acid in rain forest leaves. In: Odum, Howard T.; Pigeon, Robert F., eds. A tropical rain forest. Washington, DC: U.S. Atomic Energy Commission, Division of Technical Information: 69-70. Chapter G-6.
12. Caro, F. la; Rudd, R.L. 1985. Leaf litter disappearance rates in Puerto Rican montane rain forest. Biotropica. 17(4): 269-276.
13. Chudnoff, M.; Boone, R.S.; Goytia, E. 1969. Preservative treatments and service life of fence posts in Puerto Rico. Res. Pap. 10. Río Piedras, Puerto Rico: U.S. Department of Agriculture, Forest Service, Institute of Tropical Forestry. 30 p.
14. Cintron, Gilberto. 1970. Variation in size and frequency of stomata with altitude in the Luquillo Mountains. In: Odum, Howard T.; Pigeon, Robert F., eds. A tropical rain forest. Washington, DC: U.S. Atomic Energy Commission, Division of Technical Information: 133-135. Chapter H-9.
15. Crow, T.R. 1980. A rainforest chronicle: a 30 year record of change in structure and composition at El Verde, Puerto Rico. Biotropica. 12(1): 42-55.

16. Crow, Thomas R.; Grigal, David F. 1979. A numerical analysis of arborescent communities in the rain forest of the Luquillo Mountains, Puerto Rico. Vegetatio. 40(3): 135-146.
17. Crow, Thomas R.; Weaver, Peter L. 1977. Tree growth in a tropical moist forest of Puerto Rico. Res. Pap. ITF-22. Río Piedras, PR: U.S. Department of Agriculture, Forest Service, Institute of Tropical Forestry. 17 p.
18. Duke, James A. 1970. Keys for the identification of seedlings of some prominent woody species in eight forest types in Puerto Rico. In: Odum, Howard T.; Pigeon, Robert F., eds. A tropical rain forest. Washington, DC: U.S. Atomic Energy Commission, Division of Technical Information: 239-274. Chapter B-15.
19. Edmisten, Joe. 1970. Survey of mycorrhiza and nodules in the El Verde forest. In: Odum, Howard T.; Pigeon, Robert F., eds. A tropical rain forest. Washington, DC: U.S. Atomic Energy Commission, Division of Technical Information: 15-20. Chapter F-2.
20. Estrada Pinto, Alejo. 1970. Phenological studies of trees at El Verde. In: Odum, Howard T.; Pigeon, Robert F., eds. A tropical rain forest. Washington, DC: U.S. Atomic Energy Commission, Division of Technical Information: 237-269. Chapter D-14.
21. Ewel, John J.; Whitmore, Jacob L. 1973. The ecological life zones of Puerto Rico and the U.S. Virgin Islands. Res. Pap. ITF-18. Río Piedras, PR: U.S. Department of Agriculture, Forest Service, Institute of Tropical Forestry. 72 p.
22. Fournet, Jacques. 1978. Flore illustree des phanerogames de Guadeloupe et de Martinique. Paris, France: Institut National de la Recherche Agronomique. 1654 p.
23. Frangi, Jorge L.; Lugo, Ariel E. 1985. Ecosystem dynamics of a subtropical floodplain forest. Ecological Monographs. 55(3): 315-369.
24. Frangi, Jorge L.; Lugo, Ariel E. 1991. Hurricane damage to a flood plain forest in the Luquillo Mountains of Puerto Rico. Biotropica. 23 (4a): 324-335.
25. Heywood, V.H. 1978. Flowering plants of the world. New York: Mayflower Books, Inc. 336 p.
26. Hodge, W.H. 1954. Flora of Dominica, B.W.I.: Part 1. Lloydia. 17(1): 1-238.
27. Holdridge, L.R. 1967. Life zone ecology. San Jose, Costa Rica: Tropical Science Center. 206 p.
28. Johnston, Mark H. 1992. Soil-vegetation relationships in a tabonuco forest community in the Luquillo Mountains of Puerto Rico. Journal of Tropical Ecology. 8: 253-263.
29. Koo, F.K.S.; de Irizarry, Edith R. 1970. Nuclear volume and radiosensitivity of plant species at El Verde. In: Odum, Howard T.; Pigeon, Robert F., eds. A tropical rain forest. Washington, DC: U.S. Atomic Energy Commission, Division of Technical Information: 15-20. Chapter G-1.
30. Liogier, Henri Alain. 1981. Phytologia Memoirs III. Antillan Studies I, Flora of Hispaniola: Part 1, Celastrales, Rhamnales, Malvales, Thymedeales, Vioales. Plainfield, NJ: Harold N. Moldenke and Alma L. Moldenke, 303 Parkside Road (publishers). 218 p.
31. Little, Elbert L., Jr.; Wadsworth, Frank H. 1964. Common trees of Puerto Rico and the Virgin Islands. Agric. Handb. 249. Washington, DC: U.S. Department of Agriculture. 548 p.
32. Longwood, Franklin R. 1961. Puerto Rican woods: their machining, seasoning and related characteristics. Agric. Handb. 205. Washington, DC: U.S. Department of Agriculture. 98 p.
33. Lugo, Ariel. 1970. Photosynthetic studies on four species of rain forest seedlings. In: Odum, Howard T.; Pigeon, Robert F., eds. A tropical rain forest. Washington, DC: U.S. Atomic Energy Commission, Division of Technical Information: 81-102. Chapter I-7.
34. Marrero, Jose. 1949. Tree seed data from Puerto Rico. Caribbean Forester. 10: 11-30.
35. Martorell, Luis F. 1975. Annotated food plant catalog of the insects of Puerto Rico. Río Piedras, PR: Agricultural Experiment Station, University of Puerto Rico, Department of Entomology. 303 p.
36. Medina, E.; Sternberg, L.; Cuevas, E. 1991. Vertical stratification of delta 13C values in closed natural and plantation forests in the Luquillo Mountains, Puerto Rico. Oecologia. 86(3). 369-372.
37. Moscoso. R.M. 1943. Catalogus florae Domingensis (Catalogo de la flora Dominicana). Parte 1: Spermatophyta. New York: L & S Printing Company, Inc. 732 p.
38. Murphy, Peter G. 1970. Tree growth at El Verde and the effects of ionizing radiation. In: Odum, Howard T.; Pigeon, Robert F., eds. A tropical rain forest. Washington, DC: U.S. Atomic Energy Commission, Division of Technical Information: 141-171. Chapter D-4.
39. Odum, H.T.; Abbott, W.; Selander, R.K.; [and others]. 1970. Estimates of chlorophyll and biomass of the tabonuco forest of Puerto Rico. In: Odum, Howard T.; Pigeon, Robert F., eds. A tropical rain forest. Washington, DC: U.S. Atomic Energy Commission, Division of Technical Information: 3-19. Chapter I-1.
40. Odum, Howard T. 1970. Summary: an emerging view of the ecological system at El Verde. In: Odum, Howard T.; Pigeon, Robert F., eds. A tropical rain forest. Washington, DC: U.S. Atomic Energy Commission, Division of Technical Information: 191-289. Chapter I-10.
41. Ovington, J.D.; Olson, J.S. 1970. Biomass and chemical content of El Verde lower montane rain forest plants. In: Odum, Howard T.; Pigeon, Robert F., eds. A tropical rain forest. Washington, DC: U.S. Atomic Energy Commission, Division of Technical Information: 53-77. Chapter H-2.
42. Padgett, D.E. 1976. Leaf decomposition by fungi in a tropical rainforest stream. Biotropica. 8(3): 166-178.
43. Sauget, J.S.; Liogier, H.E. 1953. Flora de Cuba. Contribuciones Ocasionales 13. Habana, Cuba: Museo de Historia Natural de "Colegio de la Salle." 502 p.
44. Scatena, F.N.; Silver, W.; Siccama, T.; Sanchez, M.J. 1993. Biomass and nutrient content of the Bisley experimental watersheds, Luquillo Experimental Forest, Puerto Rico, before and after Hurricane Hugo, 1989. Biotropica. 5(1): 15-27.

45. Smith, Robert Ford. 1970. Preliminary illustrated leaf key to the woody plants of the Luquillo Mountains. In: Odum, Howard T.; Pigeon, Robert F., eds. A tropical rain forest. Washington, DC: U.S. Atomic Energy Commission, Division of Technical Information: 275-290. Chapter B-16.
46. Smith, Robert Ford. 1970. The vegetation structure of a Puerto Rican rain forest before and after short-term gamma radiation. In: Odum, Howard T.; Pigeon, Robert F., eds. A tropical rain forest. Washington, DC: U.S. Atomic Energy Commission, Division of Technical Information: 103-140. Chapter D-3.
47. Snyder, Noel F.R.; Wiley, James W.; Kepler, Cameron B. 1987. The parrots of Luquillo: natural history and conservation of the Puerto Rican parrot. Los Angeles, CA: Western Foundation of Vertebrate Zoology. 384 p.
48. Stehle, Henri. 1947. Notes taxonomiques, xylologiques et geographiques sur les chataigniers du genru *Sloanea* des Petites Antilles. Caribbean Forester. 8: 301-307.
49. Tropical Forest Experiment Station. 1953. Thirteenth annual report. Caribbean Forester. 14(1): 1-33.
50. Wadsworth, Frank H. 1950. Notes on the climax forests of Puerto Rico and their destruction and conservation prior to 1900. Caribbean Forester. 11: 38-47.
51. Wadsworth, Frank H. 1951. Forest management in the Luquillo Mountains. Caribbean Forester. 12(3): 93-114.
52. Wadsworth, Frank H. 1952. Forest management in the Luquillo Mountains. III. Selection of products and silvicultural policies. Caribbean Forester. 13(3): 93-119.
53. Walker, Lawrence R. 1991. Tree damage and recovery from Hurricane Hugo in Luquillo Experimental Forest, Puerto Rico. Biotropica. 23 (4a): 379-385.
54. Weaver, Peter L. 1983. Tree growth and stand changes in the subtropical life zones of the Luquillo Mountains of Puerto Rico. Res. Pap. SO-190. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 24 p.
55. Weaver, Peter L. 1994. Bano de Oro Natural Area: Luquillo Mountains, Puerto Rico. Gen. Tech. Rep. SO-111. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 56 p.
56. Wolcott, George N. 1957. Inherent natural resistance of woods to the attack of the West Indies dry-wood termite *Cryptotermes brevis* Walker. Journal of Agriculture of the University of Puerto Rico. 41: 259-311.

NOTE

Pesticides are mentioned in this paper for information only; this does not imply that their use is recommended. All pesticides must be registered by appropriate State and/or Federal agencies before they can be used. Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.