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Introduction

Balsa, the lightest of commercial timbers, has only one third the weight of soft pine. The number of uses and the demand for balsa lumber increased about three-fold during the second world war, but since the war the demand has remained at a level of more than half that of war-time. The distribution of balsa in the American tropics is from Puerto Rico westward through the other islands of the West Indies into southern Mexico and southward through Central America to Colombia, Ecuador, Peru and Bolivia.

Taxonomy

The scientific name of the balsa of Ecuador has been a subject of controversy (5). Since 1788 when the genus *Ochroma* Swartz was briefly described with a single species, *Ochroma lagopus* Swartz, a total of 10 species have been described although most workers recognize at most only two or three. The greatest increase in number of species was made when Rowlee (8) in 1919 named seven new species, bringing the total to nine. The Peruvian balsa was added as a new species by Johnston in 1928. In 1944 Little (5) summarized the nomenclature of balsa to determine the status of the balsa of Ecuador. He agreed with "the general tendency among recent workers to question the validity of the segregate species of *Ochroma*". He bases his use of *Ochroma lagopus* Swartz for the balsa of Ecuador on the fact that his herbarium material from extensive collections in Ecuador is not specifically different from the original species of balsa of the West Indies.

Balsa in Ecuador

Ecuador supplies more than 90 percent of the world market of balsa. The quantity exported annually is about 16,000,000 board feet. The environmental conditions of the coastal region of western Ecuador are generally favorable to the production of balsa timber of high quality, and the fan-like location of the river systems makes possible river transport to the seaports.

The general shape of Ecuador, which is about 1-½ times the size of Iowa, is that of a piece of pie with the Pacific coast line representing the crust. The littoral or coastal region makes up about one-third of the area of Ecuador and may be represented by that third of the piece of pie next to the crust. This coastal strip extending generally north and south is bordered on the east by the western slope of the Andes. The width of this strip is about 50 miles near the Colombian border at the north, 100 miles in the middle part and about 20 miles near the Peruvian border at the south. The climate is progressively drier southward. A strip of higher elevation bordering the coast from the mid-point southward is generally too dry for balsa. (3, 6).

The area delimited as above constitutes the balsa producing region of Ecuador. The elevation of the greatest portion of the area is less than 500 feet, although along its eastern border it may extend up the western slopes of the Andes to an elevation of 2500 feet. Along this entire eastern border it is in contact with the mountain forest covering the western slopes of the Andes from an elevation of 2000 or 2500 feet to 9000 or 10,000 feet. (7, 9).

The vegetation of this region in Ecuador in which balsa grows is classified as wet tropical forest in contrast to the tropical rain forest which occurs in Colombia (3). In spite of the occurrence of a dry season of a few to eight months duration, the general appearance of this forest closely resembles the true tropical rain forest. In virgin stands stratification is well developed. The trees are broad-leaf evergreens. The upper canopy of the forest is well over 100 feet. Many vines and epiphytes are present (1). There is a very large number of species, and constancy among different stands of apparently the same community is very low.

Experimental Area

The experimental area is located on the middle branch of the Guayas river system about 100 miles north of Guayaquil. It is about 12 miles east of the foothills of the Andes and midway north and south in the wet tropical forest. This area was selected because a large proportion of high quality balsa logs exported from Ecuador are obtained from this locality and rafted down the Quevedo river from Quevedo and adjacent towns (4). It was at Quevedo that Thor Heyerdahl, the author of "Kon-Tiki", and his crew obtained the balsa logs for the raft on which they crossed the Pacific (2). Weather data for this experimental area were taken from the records of the weather station at Cooperative Tropical Experiment Station located on the Quevedo river 15 kilometers south of Quevedo. The growth measurements and other data were obtained in the wet tropical forest of a strip extending about 3 kilometers on each side of the river for a distance of about 20 kilometers north and south of the tropical station.

Environmental Factors

The soils of the Andean outwash plain of this area are fine, sandy, and clay loams chiefly of volcanic origin. They are for the most part colluvial and alluvial and extend in depth beyond the limits of root growth of the balsa. Where tested in the vicinity of the tropical station, they were very slightly acid. On recently cleared and burned areas where most of the balsa trees grow, the soil has a friable structure to which may be attributed the high rate of percolation during the rainy season and the high water-holding capacity. In the experimental plots at the Tropical station it was possible to grow a second crop of corn, planted after the rains had ceased about the middle of May, and watered only from the moisture held in the soil. This condition is a very important factor in the growth of balsa stands.

Rainfall data in inches per month for a ten-year period are presented in Figure 1. Two facts are very apparent from the graph; the occurrence of a wet and dry season and the high variability from year to year. The curves for the years 1952 and 1953 as well as the average curve for the 10-year period are shown because these two successive years represent an extremely wide variation. Plant growth conditions are not as unfavorable during the dry season as would be expected. During the wet season rain falls almost every night and there is bright sunshine for about half of each 12-hour daytime period. During the dry season however the sky is continuously overcast with a corresponding lowering temperature and a reduction in vapor pressure deficit. The terms are relative but the wet season is the "hot" season (84° F. maximum average) and the dry season is the "cool" season (80° maximum average).

Another ameliorating influence on the climate is the occurrence of "garua", a heavy morning fog or mist which persists until 8 to 10 o'clock. During the first month of the dry season, "garua" usually occurs 22 to 24 times. The number of mornings "garua" occurs is reduced more or less gradually until the final month of the dry season when it may occur only 10 to 12 times.

Temperature, humidity, and wind data as monthly averages for 1952 and for the first 10 months of 1953 are shown in a graph in Figure 2. Contrasted to the wide variation in rainfall per month and per year, the variation in temperature and humidity from year to year are very slight and the daily variations within a given year are not great: 91 to 66° F. in temperature and 100 to 60 percent in humidity. The average monthly minimum

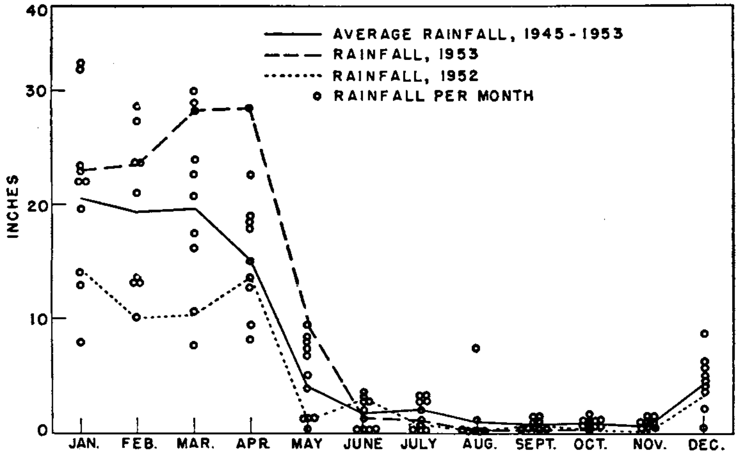

FIG. 1 RAINFALL IN INCHES PER MONTH AT THE TROPICAL EXPERIMENT STATION.

humidities are not given in Figure 2. The lowest value was for the month of November 1952: 69.6 percent. The average vapor pressure deficit for this driest month of the 20, based on the monthly average daily humidity and temperature, was 3.54 mm. of mercury. The average vapor pressure deficit for June, 1952, the least dry month, 1.48. A difference of such low magnitude would have little or no effect on the transpiration rate of plants. Under soil moisture conditions which seldom approach the wilting percentage at any great depth, drought is seldom if ever a factor in the development of a balsa stand under natural conditions unless the stand is greatly overstocked. The monthly average

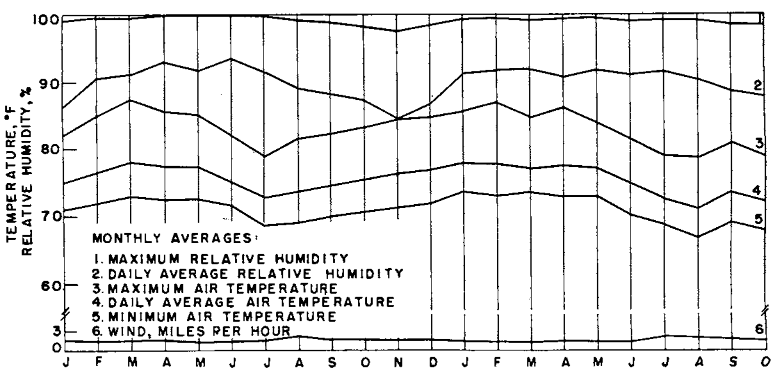

FIG. 2 TEMPERATURE, HUMIDITY AND WIND DATA AT THE TROPICAL EXPERIMENT STATION.

wind velocity does not exceed 2 miles per hour but air movement is very constant from day to day and from month to month. The absence of high winds in the central and eastern part of the coastal region of Ecuador is an important factor in the development of balsa, which is not well adapted to growth in regions of high wind velocity.

Growth Habit and Response of Balsa to Environment

The balsa in Ecuador is a fast-growing, short-lived tree with heart-shaped leaves mostly 8 to 14 inches in length. Larger leaves on young trees and on shaded and succulent branches are common. Young trees in close stands have slender, sparsely branched, almost spindly stems. In open stands young trees may branch profusely and broadly. The succulent, browish-green flowers are usually about 5 to 7 inches long and almost as wide. The fruit is an elongate, 5-valved, dehiscent capsule whose shape and short, brown, silky, hair-like fibers suggested the specific name "lagopus", rabbit's foot. Each pod contains about 1000 seeds which are enveloped by a brownish down of connected fibers. The seeds are elongate and very small and light. There are about 50,000 to 60,000 clean seeds to a pound.

The pods begin to fall toward the close of the dry season. The capsules open as they dry, releasing the light brown, finely fibrous material which is very inflammable. The fact that the seed are borne in this manner and readily released by burning is the first in a chain of circumstances which account for the role of balsa as a pioneer species in the wet tropical forest. When the "monte" (forest) has been cleared for a patch of upland rice and corn and, after drying, is burned, thousands of little piles of balsa floss explode with bursts of flame, releasing millions of tiny seeds in the soil. Balsa seed may remain viable in the soil for several years, which insures a contant seed supply in areas where the "rotation" usually calls for reclearing, burning and cropping every three or four years.

The chief characteristic that accounts for the classification of the balsa as a pioneer species in the reestablishment of forest stands following clearing and burning or other disturbance is the extreme intolerance of balsa to shades. There is scarcely a tree species in the wet tropical forest which cannot shade out the balsa when it reaches an equal or greater height. However, the rapid growth of balsa assures its dominance in occasional small areas where conditions for its establishment have been sufficiently favorable to produce fully stocked stands. In these stands dominance may be maintained for 8 to 10 or more years, until most of the trees are large enough for cutting. The trees of the last four age groups in Figure 3 were cut from such stands. The trees of the first four age groups were growing in similar but younger fully stocked stands.

The sigmoid curve of the graph represents the rate of growth of balsa for the first 8 years as accurately as it can be constructed from different fully stocked stands growing under natural conditions. Figure 4 is a picture of a part of a natural, fully stocked stand of balsa. None of the trees is older than 7 years. Some of the trees in this stand are slightly larger than the trees in the cut stands from which the upper part of the curve in Figure 3 was constructed.

Generally balsa stands are not sufficiently well-stocked to compete among themselves and therefore make more rapid growth than completely stocked stands for as long as their crowns remain above the canopy of slower growing, more tolerant species. These may attain near maximum height growth for the species (about 100 feet) and D.B.H. measurements of 25 to 36 or more inches. In such mixed stands the balsa is usually not dominant. The sigmoid curve representing the growth of these trees has a more upright and longer grand period of growth line, extending from about the third year to the seventh or eight year, than the curve in Figure 3. Beyond this point it flattens off more slowly.

Over large areas of the wet tropical forest, occasional balsa trees grow alone, or in two's and three's, in the stand of mixed hardwoods whenever there is sufficient space for a quick growing intolerant tree or two to become established and an adequate break in the canopy for their crowns to receive sufficient light for development. In openings of sufficient size, these occasional balsa trees may attain sizes as great as 42 to 48 inches D.B.H. and to 120 feet or more high. The sigmoid growth curve of some of these trees may be the most upright of all. However, balsa trees that attain diameters much in excess of 20 inches

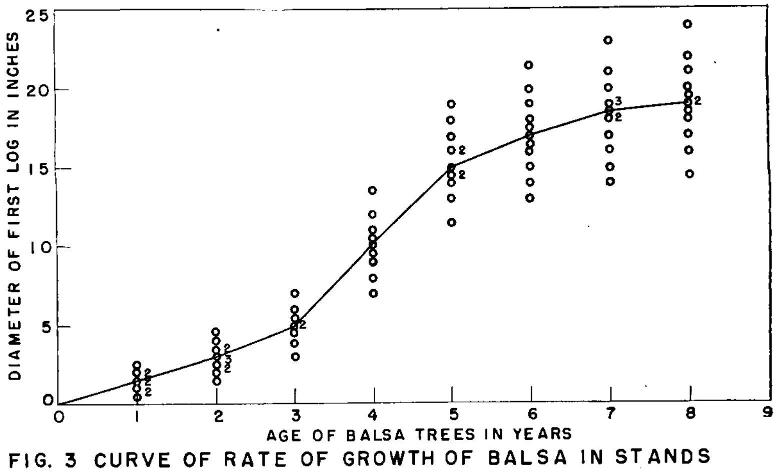

FIG. 3 CURVE OF RATE OF GROWTH OF BALSA IN STANDS DOMINATED BY THIS SPECIES.

are likely to contain water-heart and are of little commercial value.

Balsa trees, because of their constant seed supply and rapidity of growth following germination in cleared areas, become established readily in clearings of any size. Their extreme intolerance contributes to their adaptability to the plant growth conditions of the wet tropical forest rather than to those of the tropical rain forest where an intolerant, pioneer species would be subjected to a lower degree of light intensity than it could endure. Because of this fact the balsa is admirably adapted to growth in the wet tropical forest and especially in those portions of it which have a dry season of about 6 months duration. Under the conditions of overcast skies during the dry season, the occurrence of "garua" and the fertile, high water-holding capacity soils of volcanic origin, the balsa can endure the dry season and still maintain a greater rate of growth than many of the more tolerant tree species. Under these conditions it has an advantage when growing in competition with these species which it would not have if the rainfall were greater and more constant, and therefore conditions favorable for the rapid growth of more tolerant species.

At the present time there is enough balsa to supply the demand by harvesting those trees which grow more or less naturally in cleared and other open areas with very few control practices. As the demand increases, which seems very likely, the supply can be greatly increased by more careful control of the growth conditions of the balsa. This control can be attained more easily in regions in which the soil and climate conditions resemble very closely those in the vicinity of the tropical experiment station in the Quevedo area rather than in the more humid areas northward. Shade control for example will be much easier here where fewer, more tolerant trees must be suppressd than would be necessary with more rainfall over a longer period.

Clearing of cut-over land especially for balsa production would be the first step in a program to increase the supply of balsa in these favorable areas. Harvesting a crop or two of rice and corn before balsa is allowed to come in greatly reduces the quantity and quality of balsa produced. Fostering the establishment of stands as that shown in Figure 4, except much larger in area, would not be difficult if the seedlings were allowed to develop naturally following clearing and burning instead of weeding out the young trees for a year or two as is the practice in the present cropping procedure. Girdling or felling young trees of more tolerant species as necessary to make canopy room for the balsa trees as they develop is not too laborious or expensive. After the middle of the third year the young fully stocked stand would require no more care until cutting time.

Figure 4. Part of a fully stocked 7-year stand of balsa approximately one acre in extent. Number per acre 1500, D.B.H. to 24 inches, height to 70 feet. Tropical Experiment Station, August, 1953.

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