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LONCHOCARPUS, DERRIS, AND PYRETHRUM CULTIVATION AND SOURCES OF SUPPLY

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Washington, D. C.
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INTRODUCTION

Just as a number of plant substances poison man, others are toxic to certain insects and are valuable for the compounding of commercial insecticides. Among the most important are pyrethrum flowers, produced by a few species of *Chrysanthemum*, and rotenone-bearing roots, harvested from several species of *Lonchocarpus* and *Derris*.

Each of these insecticidal products has specific merit which cannot be wholly duplicated by the others, by such synthetics as DDT, or by the various metallic poisons. Aside from being effective against numerous pests, commercial pyrethrum and rotenone insecticides are also comparatively nontoxic to man and other warm-blooded animals. They may be used with safety in the household, for livestock dips and sprays, and on garden vegetables, fruits, and canning crops.

Rotenone and, to a lesser extent, related chemical substances called rotenoids are lethal to the Mexican bean beetle, wooly apple aphid, European corn borer, pea aphid, ox warble, and the cattle tick. They are also effective against fleas, cockroaches, flies, mosquitoes, and many other insect pests. Although numerous leguminous plants of the subfamily Papilionaceae have been reported to contain rotenone and rotenoids,[1] most commercial supplies are obtained at present from the roots of *Derris elliptica, D. malaccensis, Lonchocarpus urucu, L. utilis*, and *L. nicou*.[2]

These important rotenone-producing species are so closely related taxonomically that MacBride (*17*)[3] classifies them under the single genus *Derris*. From a horticultural, as well as a commercial, viewpoint it is important to maintain a separation between the genera; fortunately other systematists, including Ducke (*4*), Hermann (*9*), Killip (*14*), Krukoff (*16*), and Smith (*14, 16*) recognize a distinction between them.

Derris is native to the Far Eastern Tropics, whereas the commercial rotenone-bearing species of lonchocarpus are native to the Amazon

[1] Jones, Howard A. A list of plants reported to contain rotenone or rotenoids. U. S. D. A., Bur. Ent. and Plant Quar. E-571, 14 pp. Washington. 1942. [Processed.]

[2] Roark, A. C. Lonchocarpus species (barbasco, cube, haiari, nekoe, and timbo) used as insecticides. U. S. D. A., Bur. Ent. and Plant Quar. E-367, 133 pp. Washington. 1936. [Processed.]

[3] Italic numbers in parentheses refer to literature cited, p. 35.

Basin and the rain-forest areas of northern South America. To date, plantation culture of lonchocarpus has succeeded only in the Amazon Valley, whereas derris cultivation has been a profitable venture only in the Far East. In their native habitats, the important rotenone-bearing species of derris and lonchocarpus are lianas which take advantage of neighboring trees for support to climb to the upper canopy of the rain forests. Under cultivation *D. elliptica* assumes a decumbent growth habit unless trellised. *D. malaccensis* and the three lonchocarpus species develop as bushes. Derris produces a relatively small root system, compared with that of lonchocarpus. These distinguishing characteristics have a direct bearing on the methods used to cultivate the various plants and on the costs of root production.

In addition to the insecticidal properties of rotenone, it is also a fish poison. Infusions of macerated rotenone-bearing roots have long been used by natives of the Malay Peninsula and the Amazon Valley for this purpose. Among certain riverbank dwellers of the Amazon, it remains a practice to this day to plant small plots of lonchocarpus along with other crops necessary to their mode of subsistence living as soon as they migrate into new areas for the purpose of settlement.

A large portion of the commercial roots exported from Brazil during the past 15 years were harvested from plants found in the neighborhood of either inhabited or abandoned villages and hut clusters, where originally they had been established to provide fish poison. The Spanish word *barbasco,* meaning fish poison, is a term commonly applied in Peruvian commercial circles both to the lonchocarpus plant and to its dried roots. Other local names are timbó in Brazil, cube (*30*) in Peru, nekoe in Surinam, and haiari in British Guiana. (See table 1.)

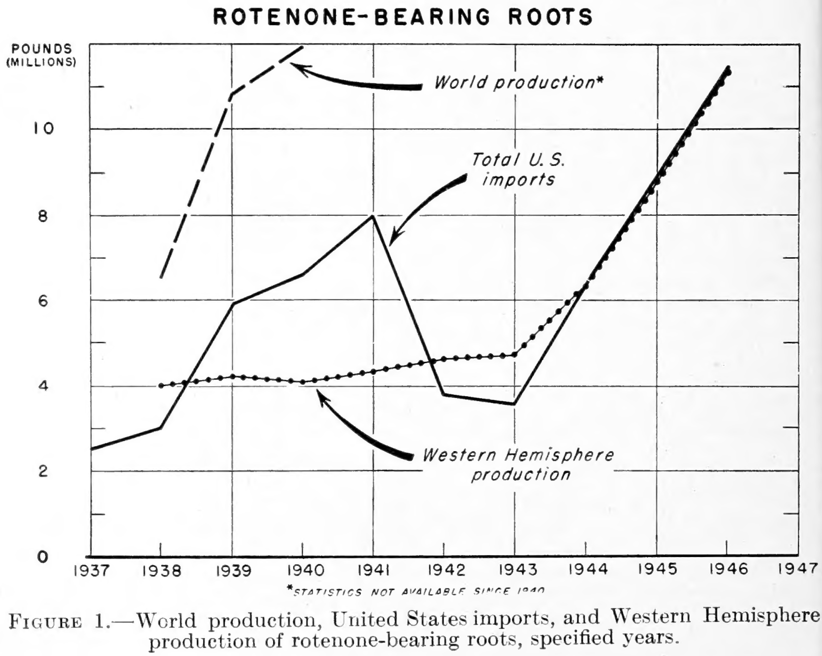

FIGURE 1.—World production, United States imports, and Western Hemisphere production of rotenone-bearing roots, specified years.

TABLE 1.—*Estimated world production of rotenone-bearing roots (derris and lonchocarpus), by country, 1938–40*

Country	Production		
	1938	1939	1940
	1,000 lbs.	*1,000 lbs.*	*1,000 lbs.*
Brazil	2, 500	1, 500	1, 000
Peru	1, 500	2, 500	3, 000
Venezuela	(1)	200	100
British Malaya	2, 000	3, 500	3, 000
French Indochina	(1)	300	150
Japan	100	650	(2) 2, 000
Netherlands East Indies	250	1, 500	1, 750
Philippine Islands	200	650	900
Total	6, 550	10, 800	11, 900

[1] Not available.
[2] Anticipated production as reported from that area.

Source: Markwood, L. N., and Arrington, Laura G. (*20*).

TABLE 2.—*United States imports of rotenone-bearing roots, crude and powdered, by principal country of origin, 1937–46*

Roots and country of origin	1937	1938	1939	1940	1941
	1,000 pounds	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*
Lonchocarpus:					
Brazil	1, 462	1, 793	1, 101	1, 047	1, 311
Peru	378	477	1, 730	2, 225	2, 525
Venezuela	-------	55	170	74	61
Colombia	-------	-------	-------	-------	-------
Ecuador	-------	-------	-------	-------	-------
Trinidad	-------	-------	-------	-------	-------
Total	1, 840	2, 325	3, 001	3, 346	3, 897
Derris:					
British East Africa	-------	-------	-------	8	15
British Malaya	402	583	2, 326	1, 842	1, 930
French Indochina	-------	-------	33	144	78
Netherlands East Indies	57	136	280	997	1, 700
Belgian Congo	-------	-------	-------	-------	-------
Philippines	111	23	262	231	377
United Kingdom	2	2	7	-------	-------
Honduras	-------	-------	-------	-------	-------
Guatemala	-------	-------	-------	-------	-------
Leeward Islands	-------	-------	-------	-------	-------
Trinidad	-------	-------	-------	-------	-------
Total	572	744	2, 908	3, 222	4, 100
Total rotenone-bearing roots shown above (crude and powdered)	2, 412	3, 069	5, 909	6, 568	7, 997

TABLE 2.—*United States imports of rotenone-bearing roots, crude and powdered, by principal country of origin, 1937–46*—Continued

Roots and country of origin	1942	1943	1944	1945	1946
	1,000 pounds	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*
Lonchocarpus:					
Brazil	193	1, 469	554	94	473
Peru	2, 503	2, 079	5, 452	8, 604	10, 862
Venezuela	-------	-------	152	60	5
Colombia	-------	5	132	5	-------
Ecuador	-------	17	24	-------	-------
Trinidad	-------	-------	13	6	-------
Total	2, 696	3, 570	6, 327	8, 769	11, 340
Derris:					
British East Africa	-------	-------	-------	-------	-------
British Malaya	653	-------	-------	-------	-------
French Indochina	-------	-------	-------	-------	-------
Netherlands East Indies	430	-------	-------	-------	-------
Belgian Congo	-------	-------	-------	45	16
Philippines	19	-------	-------	2	-------
United Kingdom	-------	-------	-------	-------	-------
Honduras	-------	-------	-------	3	-------
Guatemala	-------	-------	-------	-------	10
Leeward Islands	-------	-------	-------	-------	2
Trinidad	-------	-------	-------	-------	.1
Total	1, 102	-------	-------	50	29
Total rotenone-bearing roots shown above (crude and powdered)	3, 798	3, 570	6, 327	8, 819	11, 369

U. S. Department of Commerce, FOREIGN COMMERCE AND NAVIGATION OF THE UNITED STATES, Annual Reports.

In the prewar year 1940 the United States, which is by far the world's largest rotenone consumer, imported approximately 6.5 million pounds of crude and ground rotenone-bearing roots. This was sufficient raw material to compound about 30 million pounds of commercial insecticides. Nearly half this quantity was derris root from Far Eastern plantations. The balance was lonchocarpus root from the Amazonian sections of Peru and Brazil and from the Orinoco Valley of Venezuela. In 1946, United States imports reached nearly 11.5 million pounds of crude and ground root. Of this amount over 99 percent consisted of lonchocarpus from South America. Peruvian plantations alone accounted for 10.9 million pounds. (See table 2 and fig. 1.)

In 1848 Chinese gardeners near Singapore were observed employing infusions of derris root as insecticides. Gerardo Klinge (*15*), a Peruvian agronomist, reported in 1910 that lonchocarpus roots would kill ticks. Commercial insecticides containing rotenone extracts from derris appeared as trade-marked products in England in 1911. McIndoo and Sievers (*18*) of the United States Department of Agriculture reported in 1924 on insecticidal tests made with lonchocarpus roots. Neither derris nor lonchocarpus was imported by the United States for commercial processing until 1931. By 1937 total imports slightly exceeded 2,000,000 pounds. The 11,369,000 pounds imported in 1946 represented the largest quantity ever purchased by the United States in one year, but even that amount was not sufficient to satisfy a potential annual demand which has been estimated at about 25,000,000 pounds.

Rotenone insecticides are usually marketed as dusts or as spray and dip concentrates. The dusts generally consist of finely ground root well mixed with some inert filler, such as talc or pyrophyllite. They may also be inert powders impregnated with root extracts. Most common sprays are either emulsions of water and root powder or root extracts diluted in appropriate solvents. Livestock-dip baths may be prepared by making water emulsions of ground root or liquid extracts. Infusions of macerated fresh roots serve as effective sprays and dips.

LONCHOCARPUS

BOTANY

In recent years one of the lonchocarpus species has become the primary source of world rotenone supplies because of a steadily growing plantation industry which has developed in the Amazon headwater region of eastern Peru. As yet, botanists are not in agreement as to the name of this Peruvian plant which has become so important economically. This hesitancy may be attributed in part to a lack of flowering and fruiting herbarium collections, which are necessary for a satisfactory taxonomic decision. Krukoff and Smith (*16*) called this plant *L. utilis* after having studied their collections of leaf specimens. Hermann (*9*) prefers to classify the same plant as *L. nicou*, variety *utilis*.

Rare flowering and even less frequent fruiting are apparently characteristics of the commercially important lonchocarpus species. Research workers at Tingo María, Peru, in 1944 induced flowering of the commercial species cultivated in that area by girdling branches of 2½-year-old plants (*3*); so it is possible that taxonomists may eventually have fertile specimens to study. The type specimen of *L. nicou* was collected in French Guiana and described by Aublet in 1775. Today only leaf fragments remain of that material, and there are apparently no known fertile collections of authentic French Guiana *L. nicou* available to taxonomists.

The only well-documented species of commercial lonchocarpus is *L. urucu*, which was named by Killip and Smith (*14*) in 1930 after their explorations in the Brazilian Amazon Basin, where they gathered specimens with flowers and legumes (fig. 2 and fig. 3). *L. urucu* is the source of most of the roots exported from Brazil. Perhaps until adequate fertile collections are obtained of French Guiana *L. nicou* and of the Peruvian species, which Krukoff and Smith call *L. utilis*, the taxonomy of the most important insecticide plant produced in the Western Hemisphere will remain confused.

FIGURE 2.—Flowering specimen of *L. urucu* collected at Belém, Brazil, by W. A. Archer in September 1942. (U. S. National Arboretum photo 84747.)

FIGURE 3.—Fruiting specimen of *L. urucu* collected at Belém, Brazil, by W. A. Archer in August 1942. (U. S. National Arboretum photo 84746.)

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SOURCES OF COMMERCIAL SUPPLIES

Prior to 1939 most of the total crude and pulverized lonchocarpus root entering world markets was harvested in the Brazilian States of Amazonas and Pará. Since then, however, the quantity of roots grown for export on Peruvian plantations has steadily increased to the current figure. At the present time, judging from the volume of production, approximately 12,000 to 18,000 acres are devoted to lonchocarpus culture in eastern Peru. By comparison, the cultivation of this crop for export has hardly begun in Bolivia, Ecuador, Colombia, Venezuela, and the Guianas, to which countries rotenone-bearing species of lonchocarpus are also native. Only slightly more interest has developed in Brazil, despite that country's one-time dominance of the market.

The principal production centers in Peru are located near the villages of Lagunas, Yurimaguas, and Tingo María (fig. 4), on the

FIGURE 4.—Plantation of lonchocarpus about 3 years old; Tingo María, Peru.

Huallaga River; Jeberos, between the Huallaga and the Marañón Rivers; Contamana, on the Ucayali River; Barranca and Nauta, on the Marañón; Iquitos and Tamshiyacu, on the Amazon; and Satipo, on the Satipo, which is a tributary of the Tambo River. In Brazil plantings are found near Belém, Portel, Mazagão, and Macapá, which are close to the mouth of the Amazon; at Pôrto de Moz, on the Xingú; at Belterra, on the Tapajóz; and in the environs of several villages along the Amazon, Negro, and Madeira Rivers in the State of Amazonas (*10*). In Venezuela small plantings are reported near El Tigre, in the State of Anzoategui, and on the Orinoco islands of Urbana and El Infierno on the western border of Bolívar State (*8*).

Introductions of lonchocarpus have been made for adaptation and trial culture by agricultural experiment stations in several Caribbean and Central American countries, British Malaya, and the Philippine Islands. It seems plausible that other tropical countries have also secured living plants for local study. As yet, however, there are no accounts of successful commercial production outside of South America. Lonchocarpus introductions made by agricultural experiment stations in Puerto Rico, Guatemala, and Nicaragua have not grown well, but as yet it has not been determined whether this was due to significant differences in climate, soils, and latitude.

Since the value and technique of cultivating the plant are little known, except in Peru and a few villages in Brazil and Venezuela, many years may pass before lonchocarpus becomes established as a commercial crop in any other tropical country. If it is eventually determined, however, that the plant has a cultivation range approximating that of derris, lonchocarpus may replace derris to some extent since, under present cultural methods, the labor requirements for producing equivalent amounts of rotenone are less in the case of lonchocarpus.

CULTIVATION PRACTICES

Field Preparation

Present methods of lonchocarpus culture are those developed through trial and error by Amazon Indians and riverbank settlers who sought to provide themselves with adequate supplies of fish poison. The general procedure from land clearing to harvest is still practically the same for a common backyard barbascal as for a commercial plantation of several hundred acres. Both are often established on land that has previously been wooded, since in the rain-forest areas of the Amazon Basin the task of opening up new clearings in the forests is considered easier and more profitable than that of reclaiming old

FIGURE 5.—Field after flash burn and ready for planting; upper Peruvian Amazon.

cultivated fields from weeds and keeping them clean. This practice of clearing new land prevails, partly because draft animals, plows, and mechanical cultivators are virtually unknown.

With simple hand tools, such as the hoe and the machete, it is too difficult to combat the vigorous encroachment of grasses. Also, in certain high-rainfall areas, where the soils are excessively leached and commercial fertilizers are too costly, it is apparent that better yields can be obtained by this method than on land maintained in continuous cultivation.

Land-clearing operations generally take place during the drier months of the year so that undergrowth and the leaves and branches of fallen trees will have an opportunity to dry out sufficiently to burn. In the Amazon region there is little danger that brush fires will spread beyond the clearings into the green growth of the surrounding rain forest; so when the trash is dry enough, it is set ablaze on a clear, relatively windless day. The flash burn consumes the mass of debris within a few minutes, but slow, smoldering fires started in stumps and logs may continue for days or weeks. No further seedbed preparation is practiced by the farmer (fig. 5), who simply waits until the subsequent rainy season to plant his crops.

Propagating Material and Field Spacing

Techniques used to cultivate lonchocarpus resemble those employed by the Amazon native to grow yuca (*Manihot utilissima*), which is his principal subsistence crop. Both plants are vigorous and will return fair yields even though cultivated in a rather haphazard manner. For propagating lonchocarpus, the planters use leafless stem cuttings 10 to 18 inches in length and from ¾ to 2 inches in diameter. The average farmer exercises little care in the preparation of these cuttings, which are often needlessly bruised and crushed, or even exposed to sun and rain, before planting. As a consequence, a mortality of 50 percent, or more, is not unusual. By observing reasonable precautions, "takes" may be 80 percent or more.

The cuttings, which usually possess from three to six axial buds, are set into holes made with digging sticks, hoes, or machetes (fig. 6). They are inclined at angles varying from approximately 15° to 60°. The apical portions, with one or two buds, are left exposed, and the remainder of the cuttings are covered with soil, which is firmed around them by the tramping of the planters' feet. One or two cuttings are placed in a single hole, and sometimes two, or more, holes may be dug side by side. Some planters even dig a series of holes to form such designs as circles, squares, triangles, and rectangles. Seldom is a field laid out in rows or checkrows, since the tangle of stumps and fallen logs makes precise spacing impossible. Distances between plants and planting designs are not standard. Reports indicate a range of 3 to 12 feet, although spacing of 5 to 7 feet seems to be more common. Close spacing is generally practiced when only one or two cuttings are used at each location and where skips are likely to occur owing to poor survival of the cuttings.

Interplanting

The average rural Amazonian is a subsistence farmer and hunter. He grows such crops as yuca, beans, corn, rice, bananas, plantains, and okra to assure himself a minimum food reserve. He also gathers

FIGURE 6.—Planting lonchocarpus cuttings; eastern Peru.

a portion of his sustenance from the forests and the rivers. Wild nuts, fruits, roots, palm hearts, fish, and game contribute to his diet. He requires a small amount of money to buy tools, clothing, patent medicines, ammunition, and other essentials. Lonchocarpus is a cash crop ideally suited to his needs. It requires 2½ to 3 years to reach maturity, and during the first year the plants, while still small, can be conveniently interplanted with food crops which will not interfere with the development of the lonchocarpus.

During the second and third years the lonchocarpus grows to a height of 6 to 8 feet, and the plantation broadens into a bushy thicket. At that stage interplanting becomes impractical, although mats of bananas, plantains, and pineapples which have become established are left undisturbed. The average planter has several small lonchocarpus fields at various stages of maturity, and in those which have recently been established he has little difficulty finding room for his subsistence crops.

Weeding

Using hand tools, as is the present custom, the average family raising lonchocarpus cannot maintain more than 5 to 6 acres in production at any single time. The experience of growers at Lagunas, Peru *(11)*, in 1943 showed that a hectare or 2.4 acres of 2½- to 3-year-old lonchocarpus on virgin land, which will normally yield about 10,000 pounds of green root or 5,000 pounds of air-dry root, requires an average of 300 man-days of labor. This figure was reduced to averages of 115 days for clearing and burning the virgin forest, 20 days for cutting up stems of mature plants for propagation material and planting them, 85 days for chopping weeds, and 80 days for harvesting.

On old cropland approximately 360 to 400 man-days were required to produce such a crop. The initial effort to clear the land was less, but considerably more time was spent in chopping back weeds with a machete during the subsequent years. Once established, a field of lonchocarpus requires no attention other than occasional weedings until harvesttime. If the stand is a relatively full one, the plants, as they grow taller and broader, tend to shade out weed growth.

Harvest and Preparation for Market

The harvesting of lonchocarpus roots is a task requiring stamina. The fresh roots of individual 2½-year-old plants will ordinarily weigh from 1 to 5 pounds. As a general rule, most of the roots spread out laterally, but a few grow almost directly downward (fig. 7). The

FIGURE 7.—Exposed root system of lonchocarpus; eastern Peru.

gatherer's job is to salvage as much of the entire root system as possible.

To accomplish his work, he first severs the trunk of the plant about 1.5 feet from the ground with a few machete slashes. He then pries under the crown of the plant with a long stout, sharp-pointed pole, which he drives into the ground with several vigorous jabs. By exerting some leverage on the end of the pole, he is able to lift the crown slightly above the level of the soil so that he can see where the main roots are attached. He then severs the roots on one side of the plant and pulls them from the ground individually. If they are very large roots, or if they penetrate more than a few inches below the surface of the ground, he may be obliged to pry them loose with his stick or dig them out with his machete. The roots still attached to the crown are more easily removed by pulling backward on the attached butt of the stem and ripping them out of the soil, sometimes with the assistance of the digging stick, or machete.

FIGURE 8.—Roots of selected lonchocarpus plants on experimental drying racks of caña brava; Instituto Quimico Agrícola Industrial, Iquitos, Peru.

The operation requires a strong back and strong arms, and only a man of considerable endurance can engage in this task for more than 5 or 6 hours a day. The average farmer gathers and carries away from the field about 125 pounds of fresh roots in a day's time. To facilitate carrying, he ties the roots into a single large bundle securely bound with long pieces of forest liana. Usually the bundles are bought from individual growers by local dealers, who, in turn, sell to exporters in the principal shipping centers.

Roots for export in crude form are kept in storage for several months until their moisture content has been reduced to approximately 20 percent of their weight. When freshly dug, they contain about 60 percent moisture. In preparation for export, crude roots are baled and wrapped in burlap or unbleached muslin. On the ocean voyage from the Amazon to the United States, they usually lose considerable moisture and arrive in a fairly dry condition. Local grinding industries have been established in Iquitos, Peru, and Belém, Brazil. Roots for grinding are first air-dried (fig. 8). Then they are chopped and oven-dried before being passed into the mill. The final product, all of which is 200-mesh, or finer, is packed into bags for shipment (fig. 9 and fig. 10).

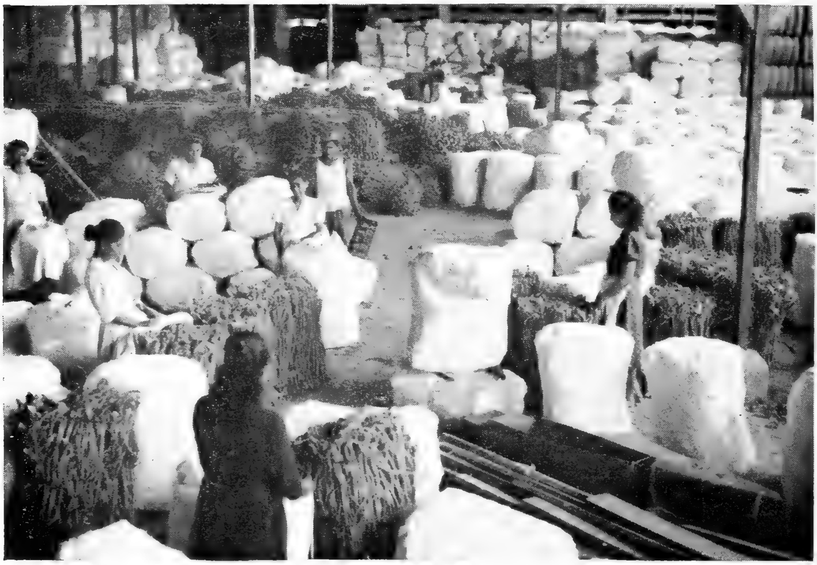

FIGURE 9.—Packing lonchocarpus root for export; Victor Israel warehouse, Iquitos, Peru.

SELECTION OF SUPERIOR-QUALITY STRAINS

The commercial value of lonchocarpus roots on the United States market is determined by their rotenone content, even though insecticide manufacturers and entomologists recognize the secondary importance of the rotenoids. Consequently, the growers of both lonchocarpus and derris are particularly interested in cultivating those strains which will yield roots of highest possible rotenone percentage. As with many other economic plants, the first major task of selecting superior strains from nature's miscellaneous variety was probably accomplished by primitive man. Perhaps in their search for effective fish poisons, the aboriginal inhabitants of the South American rain forests discovered and propagated some of the more potent lonchocarpus plants. The majority of contemporary commercial barbascales have been established from lines of plants perpetuated by the Indians and more recent immigrant settlers.

When the commercial possibilities of lonchocarpus production were recognized both in Brazil and Peru in the early 1930's, the most enterprising mercantile houses, operating through their rural intermediaries, established collections of living plants from the areas where they purchased the best grades of roots. In Peru a few of these introduction gardens eventually expanded into community plantations, where individual families now grow a few acres each and where the total area dedicated to lonchocarpus in some cases ranges from 1,000 to 3,000 acres or more.

In 1942 the Instituto Agronomico do Norte at Belém, Brazil, began a systematic study of hundreds of mature individual lonchocarpus plants of *Lonchocarpus urucu*, Killip and Smith, and also *L. utilis*, A. C. Smith, which plant explorers had brought to Belém. Chemical analyses of samples taken from the roots of these individuals revealed a range in rotenone content from 0.9 to 20.1 percent among 148 plants of *L. utilis* which were estimated to be between 3 and 5 years of age. Weights of fresh roots harvested from these individuals varied between 20 and 3,895 grams. At the same time 232 individual *L. urucu* plants, approximately 3 to 5 years of age, were studied in the same way. Their rotenone content ranged from a low of 2.2 to a high of 11.2 percent, and fresh-root weights varied between 25 and 6,420 grams. At the present time average shipments of commercial root contain from 4 to 6 percent rotenone.

FIGURE 10.—Transferring export bundles of lonchocarpus roots to the dock warehouse; Iquitos, Peru.

An interesting feature of the Instituto Agronomico do Norte's work is the observation that certain *L. urucu* strains producing high root weight may be more profitable to cultivate than the commonly preferred *L. utilis*, which usually produces a higher rotenone content but less root weight during an equal growth period. As technicians of the Instituto Agronomico do Norte emphasize, the commercial producer should be interested in achieving the highest total of rotenone per acre per year.

Work similar to that being done in Belém was begun by the author in 1943, when he was assigned to the Estación Experimental Agrícola de Tingo María in Peru. Since *L. utilis*, according to Krukoff and

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Smith, is the principal lonchocarpus species cultivated in Peru, practically all 274 collections made from major producing areas on the Marañon, Huallaga, and Amazon Rivers consisted of this type. Subsequent chemical analyses of the roots revealed a range in rotenone content from less than 1 to a high of 6.59 percent. The air-dry-root weights of 32 plants, 2½ years old, ranged between 147 and 789 grams. Of nine 5-year-old plants, the lowest air-dry-root weight was 705 grams and the highest 1,620 grams.

During the years 1944 and 1945 Peruvian technicians attached to the Estación Experimental Agrícola de Tingo María made several hundred additional lonchocarpus collections from other important commercial growing areas in eastern Peru. Cuttings from these plants were set out in introduction gardens, and their roots are now being analyzed. As at the Instituto Agronomico do Norte in Belém, the objective of the Peruvian investigations is to establish and increase clones of lonchocarpus which can be distributed to commercial growers for more profitable production. Similar research is being undertaken at the Estación Experimental Agrícola del Ecuador at Pichilingue on the Vinces River.

DERRIS

Prior to the recent war derris roots grown principally in British Malaya, the Netherlands East Indies, the Philippine Islands, and Formosa constituted the main source of the world's rotenone supply. Derris plants have been introduced into most of the tropical countries of the Western Hemisphere, but as yet they have not achieved commercial importance. Recently, however, some excellent high-rotenone-yielding clones were acquired which may contribute materially to advancing derris as a commercial crop in the American Tropics. Far more experimental research has been conducted on derris than on lonchocarpus. Most of these investigations were made in Puerto Rico, the Netherlands East Indies, and in British Malaya.

Several species of derris are known to contain rotenone, but only *Derris elliptica* and, to a lesser degree, *D. malaccensis* remain commercially important. In the Federated Malay States, the principal exporter of derris, the varietal types of *D. elliptica* include not only the popular Sarawak Creeping and Changi No. 3 but also, among others, the Singapore Nos. 1 and 2 and the Changi Nos. 1 and 2 (*23*). The Sarawak Creeping possesses considerable vigor and has a wide range of adaptability, whereas certain clones of Changi No. 3 are superior in rotenone percentage and also develop well under favorable environmental conditions. A few varieties of *D. malaccensis*, including the Sarawakensis or Sarawak Erect, Tuba Merah, and Kinta Type, have been cultivated in the Federated Malay States, even though their content of rotenone is reportedly small, because their roots contain high percentages of rotenoids. The market value of these is low, compared with that of the best *D. elliptica* varieties, which are sold on a rotenone-content basis.

VARIOUS CULTURAL PRACTICES

Native growers and agricultural experiment stations have developed a number of different methods of derris culture, which are reviewed by

Sievers.[4] In the Far East the plant is grown as a supplementary cash crop by native subsistence farmers and has been tried as an estate enterprise by a few of the larger agricultural companies. It has also been interplanted as a catch crop on new rubber and kapok plantations. Mature stem cuttings, usually between 8 and 14 inches in length, are used as propagating material, and a common practice is to place them in nursery beds of sandy soil for 3 to 6 weeks to develop roots before setting them out in the field.

Among some growers it is customary to set cuttings directly in the field without previously rooting them in nursery beds, although weeding expenses are said to be higher under this system, since a longer time elapses until vine growth covers the fields and aids in suppressing weed competition. When either rooted or nonrooted cuttings are planted in the fields, they are usually spaced approximately 2 by 2 feet to 3 by 3 feet. This task is performed during a rainy season, and one or two cuttings may be set in each location. Land preparation in Perak, Federated Malay States, is accomplished by chopping and burning off high bush where it exists and by burying any weeds and lalang grass that may be present by loosening the soil to a depth of 18 inches and turning them under (*22*).

Trellising on poles is sometimes practiced in the Netherlands East Indies, where it is said yields are thereby increased about 30 percent. One method of pole trellising consists of making tripods by crossing two stakes of one row of plants with one stake of an opposite row. Three plants then grow on the tripod for support. Trellising involves the expense of cutting poles and training plants to grow on them, but it prevents stems from rooting at nodes, which they would do if they were left in contact with the ground. The tendency of trailing derris to root from stem nodes results in the production of many fine rootlets, which are difficult to recover at harvesttime, whereas roots concentrated at the base of trellised plants are more easily dug (fig. 11).

Where trellised plants are involved, vine clearing preparatory to harvest consists of severing main stems and stacking them aside, but in cases where fields have been left to grow in a prostrate manner the job of cutting the matted vines and rolling them away in preparation for harvest is a laborious and expensive task (*25*). It is often remarked that trellised derris requires more weeding and that trailing derris suppresses competitive growth after the first year.

In many places where derris is grown, the top growth of trailing plants never quite succeeds in suppressing the competition of vigorous grasses. The resulting weeding costs may easily be greater than if the plants were trellised, since the decumbent vines must be lifted aside so that grass underneath them and growing up through them can be cut back. Adequate experimental trials for the purpose of comparing the relative costs of root production by trailing and by trellised plants remain to be made.

Apparently one of the most critical factors involved in successful derris culture is the selection of the proper soil, which should be somewhat sandy, or at least completely friable, so that root digging will be

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[4] SIEVERS, A. F. THE PRODUCTION AND MARKETING OF DERRIS ROOT. U. S. Bur. Plant Indus., 24 pp. [Mimeographed copy in U. S. Dept. of Agr. Library, Washington, D. C.]

simplified. In Puerto Rico, Moore (*25*) found that harvesting costs amounted to 64 percent of total labor expenses involved in growing 2.3 acres of derris on a heavy clay soil. Milsum and Georgi (*23*) report that entire root systems of plants can easily be lifted with an Assam fork when they are grown on sandy soils.

Climate, too, is obviously a factor in the economy of production. Where dry seasons are prolonged, plant roots penetrate the soil deeply, thereby making the digging of them more difficult. In the Amazon Valley climatic conditions promote shallow root development on the part of lonchocarpus. The manner in which the derris root system will develop under the same conditions is being studied both in Peru and Brazil. A root-development study, made at Mayagüez, P. R. (*24*), showed that 81 percent of the derris roots were located in the top 16 inches of the soil.

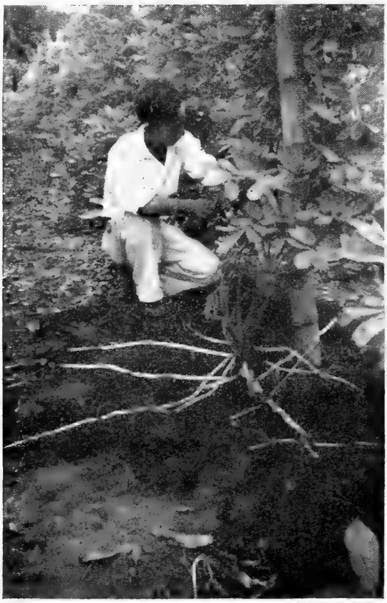

FIGURE 11.—Trellised derris, root system exposed; Santa Ana, El Salvador.

Derris is said to have been grown successfully at altitudes up to 4,750 feet above sea level (*1*). In Puerto Rico the rate of development during the first year of growth is noticeably slower at 2,400 feet than at sea level and at 1,400 feet (*25*). While there is some difference in custom among planters as to cultural techniques and also some hesitancy on the part of research workers to prescribe a hard-and-fast routine for farmers to follow in growing derris, there is general agreement that the plants, if they have developed normally, should be harvested between the ages of 18 and 27 months. Moore and Jones (*27*) have shown that the greatest amount of rotenone is stored in the roots of *D. elliptica* during flushes of growth. In a greenhouse experiment, plants that were forced to grow rapidly by abundant applications of fertilizer and water, with some reduction of light, stored, on a percentage basis, 3.9 times as much rotenone in their roots as plants that were retarded.

Unpublished data, obtained by Jones, White, and Pagan at the Puerto Rico Agricultural Experiment Station, show that although rotenone percentage does not always increase with age, and may even decrease, the total amount of rotenone per acre may increase up to an age of 36 months. This work indicates that the economical age of harvest might be extended beyond the present recommended range of 18 to 27 months, providing a reasonable increase in total rotenone continues and as long as the percentage remains at or above the commercially preferred 5 percent.

CULTIVATION IN PUERTO RICO

Although the rural laborer's wage in Puerto Rico makes derris growing unprofitable on that island, research workers at the United States Department of Agriculture's Puerto Rico Experiment Station at Mayagüez have conducted important studies on cultural techniques, which might be of use to planters in other countries.

Nursery

Moore's (*25*) studies at the Puerto Rico Experiment Station resulted in the recommendation that 12-inch cuttings of mature stems be used as propagating material. These are rooted in unshaded nursery beds consisting of ridges 8 inches high by 18 inches wide and spaced 4 feet from center to center. The ridges are opened transversely with a hoe, and the cuttings placed at an angle of about 45° from the horizontal. All but the tips of the cuttings are covered with soil (fig. 12). Moore prefers friable clay or clay loam soils for nursery beds, since they erode less easily. (In the Far East sandy soils are preferred.) Moore also suggests a minimum of 6 weeks and preferably 3 months in the rooting nurseries.

Working with indolebutyric acid, Cooper (*2*) found that leafy greenwood cuttings of derris make excellent propagating material when butt ends are treated with 50 percent ethyl-alcohol solutions containing 5 mg./ml. of this root stimulator and then placed in closed sash-covered frames for 3 weeks before transplanting to field nurseries. When there is a limited amount of propagating material of, for example, special high-rotenone-yielding clones, this method can be used to take advantage of green vinewood which would otherwise be lost.

Transplanting

This operation should take place when rains are sufficiently frequent to keep the cuttings from drying out before they become established. When they are ready for transplanting, the viny tops which develop in the nursery beds are trimmed back with machetes to stumps about 6 inches long. Then the cuttings are lifted from the beds for transfer to the field, which should be weed-free and in good tilth as the result of previous plowing and disking. At the Puerto Rico Experiment Station, Moore used plows to open 4-inch-deep planting furrows spaced 3 feet apart. Every 2 feet a rooted cutting was laid flat in the bottom of the furrows with the vine stump protruding above the ground level. In applying fertilizer, about 2 inches of soil was firmed over the cuttings; then the fertilizer was scattered and covered up with the remaining earth. When fertilizer was not applied, the cuttings, with the exception of the protruding vine stumps, were covered with soil in one operation.

FIGURE 12.—Rooted cutting of *Derris elliptica* in nursery ready for transplanting to field.

Weeding and Trellising

Because local conditions may determine whether or not it is more or less profitable to trellis derris rather than to let it trail on the ground, Moore makes no specific recommendation as to this practice. His experiments have shown that weeding expenses increase when plants are trellised and that the rotenone content of roots is reduced one-eighth as compared with that of prostrate plants. However, root yields of trellised plants increased 75 percent over those not trellised. If the ground is properly cleared in the first place, trailing plants may be kept clean by mechanical cultivation for the first few months until there is danger of damaging tender young stems; then hand weeding with hoes, or machetes, becomes necessary.

Mulching

Keeping trailing derris weed-free for the first year or so, until it is somewhat capable of suppressing competition by the density of its own foliage, is a major production expense. As the result of mulching studies at the Puerto Rico Experiment Station, White, Pagan, and

Manguel [5] observed that only one-third as many man-hours were necessary to hand-weed derris plots mulched with 6 inches of sugarcane leaves as compared with control plots not mulched.

Although the application of cane trash constituted an additional labor cost, yields were in some cases 31.7 percent greater, and rotenone content of the roots was slightly, although not significantly, higher than those of control plots. They recommend mulching as a commercial practice when suitable material can be applied economically. In an unpublished comment to the writer, White remarked that a good mulch decreased the amount of rooting at the nodes, thereby aiding removal of the vines.

Harvest Methods and Yields of Roots

Clearing the tops from a field of unmulched trailing derris (fig. 13) is complicated by the tendency of matted vines to become rooted to the soil. These tops are removed by cutting the thick blanket of

FIGURE 13.—*Derris elliptica*; ground cover of leaves and vines is cleared away preparatory to digging the roots. Vines are cut by machete and then rolled into piles with long poles.

vines into strips about three rows wide and 18 to 20 feet long. Machetes are used to sever the mat from the ground. This is rolled up and moved aside as it is cut loose. Once the vines are out of the way, the field can be plowed either with a tractor or with oxen.

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[5] WHITE, DAVID G., MULCHING TROPICAL PLANTS; and WHITE, DAVID G., PAGAN, CALEB, and MANGUEL JOSÉ C., THE EFFECTS OF MULCHING *DERRIS ELLIPTICA*. [Manuscripts accepted for publication in Journal of Tropical Agriculture (Trinidad).]

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If a tractor is used, a 16-inch-deep furrow can be turned and the roots removed by hand as the clods are forked over by harvesters stationed at intervals along the field. If oxen are used, two 8-inch furrows must be plowed, one below the other, so as to break open the ground to a depth of 16 inches for the harvesters. The roots need only to be separated from clods of earth and any attached pieces of vine before they may be dried and packed in bales for shipment.

Derris roots, being much smaller in diameter than those of lonchocarpus, dry out in a week or two if left outside in clear weather or within 3 weeks if dried under well-ventilated shelters. In Puerto Rico experimental plots, 25 to 27 months old, yielded from 885 to 1,738 pounds of air-dry roots per acre when the trailing system of culture was used and 3,040 pounds when the plants were trellised.

DESIGN OF A MECHANICAL HARVESTER

Since the expenses of harvesting derris by present hand methods may easily exceed the total of all other production costs when a trailing

FIGURE 14.—Whirlwind terracer being used in derris harvest trials for digging roots after tops were removed with other equipment. Tractor was operated in low gear and terracer in low speed.

crop is grown on heavy soils under climatic conditions promoting deep rooting, the development of mechanized methods has seemed desirable. Workers at the Estación Experimental Agrícola del Ecuador [6] at

[6] NUTT, GEORGE B. REPORT ON DERRIS HARVESTING INVESTIGATIONS CONDUCTED AT PICHILINGUE, ECUADOR. 11 pp., illus. August 1945. [Unpublished manuscript filed in T. C. B., O. F. A. R.]

Pichilingue, Ecuador, have attempted methods of harvesting derris root mechanically, with encouraging results In these initial studies a universal-type tractor mower, equipped with bush guards, canning-pea-type vine lifters, and heavy dividers on both inside and outside shoes, proved to be a practical device for cutting prostrate derris vines prior to removal from the field. For windrowing vines, an unmodified side-delivery rake was not entirely satisfactory, since it clogged when it could not rip aside those vine runners left uncut by the mower.

A high-speed vertical screw plow drawn by a heavy-duty tractor (fig. 14) was found capable of cutting 12- to 13-inch-deep furrows and at the same time was able to throw the embedded derris roots free and cut-clean from soil where they could easily be picked up by hand.

SELECTION OF SUPERIOR VARIETIES

When derris first became a product of commercial importance, a relationship between species and the rotenone content of their roots was recognized. Further investigations revealed that certain selections within species were superior to others; thus, a considerable number of promising clones were segregated. Others are still being established in the hope that roots of even better quality can be grown so as to make cultivation of the crop more profitable.

In 1936, experiments reported by research workers in the Federated Malay States (*5*) indicated that the insecticidal value of derris roots depends more upon the genetic qualities of parent plants than upon minor differences in soils and growing conditions. Most pioneer work in selecting superior derris stocks was undertaken in the Federated Malay States and in the Netherlands East Indies. Perhaps the root of highest rotenone content now obtained is from certain clones of the Changi No. 3 variety of *D. elliptica*.

From time to time, strains of derris were introduced by agricultural stations in the Tropics of the Western Hemisphere, but it was not until Walter Bangham of the Goodyear Rubber Plantations Co. brought 13 outstanding selections of Changi No. 3 to Panama, in 1935, that research workers in the American Tropics were provided with the high-quality foundation stocks which may make derris cultivation profitable in that part of the world. These clones, originally obtained from Malayan stocks, were grown first in Sumatra and later on the Goodyear Pathfinder Estate at Kabasalan, Zamboanga, Philippine Islands. From there, propagating material was taken by Bangham to the All-Weather Estate near Ciricito, Panama.

At that time it was planned to use derris as a cover crop on rubber plantations that the Goodyear Rubber Plantations Co. was establishing at All-Weather. In 1939 Atherton Lee, then director of the Puerto Rico Experiment Station, visited Panama and learned about Bangham's derris. Arrangements were made to ship propagating material to Puerto Rico in 1940. Living material of 9 of the 13 clones reached Puerto Rico, where subsequent experiments indicated that some of the numbers would produce roots containing as much as 10 percent rotenone (*13*).

In 1943 the Office of Foreign Agricultural Relations sent the writer to the All-Weather Estate, which had subsequently been purchased by the Inter-American Institute of Agricultural Sciences, to collect cuttings of the remaining 4 clones. By that time the introduction garden at All-Weather had been abandoned, and the markers which originally identified the separate clones were illegible, missing, or out of position. It was therefore necessary to harvest individually the 275 plants which were in the introduction garden.

The root system of each plant was sent to the Estación Experimental Agrícola del Ecuador for chemical analysis. Cuttings were also sent there, as well as to the Puerto Rico Experiment Station, the Estación Experimental Agrícola de Tingo María in Peru, the Servicio Técnico Agrícola de Nicaragua, the Inter-American Institute of Agricultural Sciences in Costa Rica, the Instituto Agropecuario Nacional in Guatemala, and to the Canal Zone Experiment Gardens, Summit, C. Z. After field trials at these stations, any numbers which may prove to be consistent high-rotenone producers will be multiplied and distributed to commercial growers.

Quantitative chemical tests for rotenone involve considerable time and expense. The analysis of hundreds of root samples, which might be necessary in the search for superior planting stock, could be very costly to the institutions undertaking the investigations. Pagan and White [7] have shown that a close and dependable correlation exists between rotenone and total ether extractives. They believe that the easiest and quickest method of evaluating large numbers of samples with reasonable accuracy is to determine their total chloroform extractives. Samples showing real superiority can be segregated in this way and their true value then determined by quantitative tests for rotenone.

PYRETHRUM

The flowers of *Chrysanthemum cinerariaefolium*, known as pyrethrum, constitute one of the most important, as well as one of the oldest, recognized insecticidal materials of plant origin. Dried, pulverized flowers, sometimes called "insect powder," and floral extracts have wide application in the control of household, livestock, and crop pests. Their toxic action is due to substances known as pyrethrins, which usually amount to only 0.8 to 1.3 percent of the weight of the dried flowers.

Although rotenone, nicotine, and certain inorganic poisons, as well as several synthetics, including DDT, may be substituted for pyrethrum to some extent, none of them possess as rapid a paralyzing effect or "knock-down" which makes its action so spectacular. For use against insects quickly stunned but not killed by pyrethrum, it is blended with other more specifically toxic insecticides.

Pyrethrum powder and extracts are nonpoisonous to all but the relatively small number of human beings who are somewhat allergic to it.

Among the insects most susceptible to pyrethrum are mosquitoes, flies, cockroaches, bedbugs, body lice, fleas, Mexican bean beetles,

[7] PAGAN, CALEB, and WHITE, DAVID G. THE EVALUATION OF ROTENONE IN *DERRIS ELLIPTICA* ON THE BASIS OF TOTAL CHLOROFORM EXTRACTIVES. [Unpublished manuscript to appear in the Journal of Association of Official Agricultural Chemists.]

cabbage worms, celery leaf tiers, potato leafhoppers, beet leafhoppers, aphids, and tobacco flea beetles. During the recent war enormous quantities of pyrethrum were processed into aerosol sprays used to destroy anopheles mosquitoes in malarial regions where troops were concentrated. Aerosol sprays containing flower extracts, sometimes in combination with DDT, are now used as household insecticides. The effectiveness of pyrethrum sprays is considerably increased by blending with about 5 percent of sesame oil obtained from the seed of *Sesamum indicum*. For certain purposes, the pyrethrin content of sprays can be reduced as much as 40 percent without impairing their efficiency when sesame oil, which has no inherent insecticidal value, is used as a synergist. The effectiveness of pyrethrum sprays is also increased by the addition of certain synthetic synergists. The most important of these are piperonyl cyclohexenone and piperonyl butoxide (*29*).

C. cinerariaefolium, native to the Dalmatian coast of Yugoslavia, is a temperate-climate plant which is also successfully cultivated in certain high-altitude regions of the Tropics where the mean average temperature does not exceed 70° F. Although the crop has been grown experimentally in the United States and several north-European countries, it has not achieved commercial importance, because its excessive labor requirements and the comparatively low market value of the flowers make its culture unattractive in countries where wage scales are high.

In the normal prewar year of 1938 world production of pyrethrum reached 16,173 short tons (table 3). In the same year the United States imported 7,268 short tons or the equivalent of nearly 45 percent of the total crop. Since the United States is by far the largest market for pyrethrum flowers, normally purchasing about half the total world harvest, data (table 4) showing sources of supply from 1933 through 1947 give a rather interesting indication of the way in which production of this crop has increased, or declined, in various parts of the world during recent years.

TABLE 3.—*Pyrethrum production, by principal producing countries, 1935–40*

Country	1935	1936	1937	1938	1939 [1]	1940 [1]
	Short tons	*Short tons*	*Short tons*	*Short tons*	*Short tons*	*Short tons*
Belgian Congo	(2)	(2)	(2)	(2)	24	110
Brazil	250	250	250	300	300	600
Japan	12, 200	13, 776	12, 000	12, 858	11, 283	5, 167
British East Africa (Kenya)	652	1, 165	1, 087	2, 015	3, 115	5, 472
Yugoslavia	697	706	702	1, 000	950	(2)
Total	13, 799	15, 897	14, 039	16, 173	15, 672	11, 349

[1] Estimated.
[2] Not available.

Compiled by Office of Foreign Agricultural Relations from U. S. Consular reports and other trade data.

TABLE 4.—*United States imports of pyrethrum (crude), 1933–47*

Country of origin	1933	1934	1935	1936	1937
	1,000 pounds	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*
Brazil		4			1
British East Africa			66	1,614	1,423
China			2		
Italy	446	114	66	61	277
Japan	9,066	10,094	15,204	9,934	17,850
Russia	84	38	5		
United Kingdom		42	81	29	22
Yugoslavia	839	299	154	119	519
Total	10,435	10,591	15,578	11,757	20,092

	1938	1939	1940	1941	1942
	1,000 pounds	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*
Belgian Congo		2	17	179	223
Brazil	497	80	78	11	397
British East Africa	2,864	5,524	10,387	10,069	8,830
Italy	28	78			
Japan	10,896	7,486	2,031	762	
Peru			1		2
United Kingdom	34	11	11		
Yugoslavia	218	388	66		
Total	14,537	13,569	12,591	11,021	9,452

	1943	1944	1945	1946	1947
	1,000 pounds	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*
Belgian Congo	200	770	3,402	4,923	3,490
Brazil	593	2,203	2,253	1,880	312
British East Africa	5,985	7,685	12,597	13,520	4,205
Peru				23	48
Chile			16	13	
Ecuador				1	
Guatemala			3	3	26
Haiti				1	1
Union of South Africa				112	
Total	6,778	10,658	18,271	20,476	8,082

From about 1860 until the First World War, Dalmatia supplied most of the pyrethrum imported by the United States. When this source was cut off by hostilities in 1914, production expanded rapidly in Japan, where cultivation of the crop had commenced in 1881. Between 1931 and 1935, Japan produced from 85 to 97 percent of the pyrethrum imported by the United States. In 1928 pyrethrum was introduced into Kenya, British East Africa, by Gilbert Walker, a planter, and by the Kenya Department of Agriculture. In 1932 commercial production was begun, and a year later the Kenya Pyrethrum Growers' Association was formed (*12*). This association, through the official pyrethrum board, which it elects, has standardized classification, price, and marketing procedures in a way that has proved highly profitable to the Kenya growers, who by 1940 were supplying the United States with over 82 percent of its requirements. During the recent war years United States imports from Kenya temporarily decreased somewhat, whereas supplies from two important new producing areas, the Belgian Congo and Brazil, advanced considerably.

BOTANY

Several species of the genus *Chrysanthemum* have been reported to possess insecticidal properties, but only three are recognized as worthy of consideration: *C. coccineum* (also known as *C. roseum*), *C. marschallii*, and *C. cinerariaefolium*. Of these the last-mentioned is so superior that it has become almost the exclusive source of commercial pyrethrum. This plant, and especially its flower, is similar in appearance to the common field daisy, *C. leucanthemum*, which is of no value as an insecticide. *C. cinerariaefolium* is a perennial, which when mature may produce floral stems 18 to 30 inches tall. Under cultivation, single plants grow into large mats, ordinarily 8 to 15 inches in diameter at the crown. The leaves may be distinguished from the common daisy in that they are deeply lobed, usually into three primary divisions, and the lobes are more or less deeply cut. The floral stems are long, usually erect, and nearly without leaves. The heads have white rays and yellow disk florets. Over 80 percent of the insecticidal pyrethrins are concentrated in the ovaries of fully opened flowers. Martin and Tattersfield (*21*) analyzed segments of fully open flowers with at least one-quarter of the disk florets open and no parts missing. They found the following distribution of pyrethrins in the various floral parts:

Floral parts:	*Composition of flowers (percent)*	*Total pyrethrins (percent)*
Petals	25. 2	0. 18
Receptacles and involucral scales	20. 4	. 27
Disk florets, excluding ovaries	31. 4	. 48
Ovaries	23. 0	4. 54

CULTURAL PRACTICES

Commercial pyrethrum is propagated both by seed and by rooted crown divisions commonly called "splits." Most research workers agree that over a period of years plants grown from seed produce larger total yields than those propagated by splits. Seedlings are generally germinated in specially prepared nurseries and later transplanted to the field (fig. 15). Usually they do not flower until the second year, but thereafter they may bear heavily for 3 to 4 years, and, even though yields may then decline, plantations may continue to produce satisfactorily for a few additional years. In the Tropics plants grown from splits will begin flowering within several weeks after they are set in the field. In the United States a satisfactory crop is not obtained until the second year. The yields and economic life of plants grown from splits may be less than those of seedlings, but propagation expenses are lower, and the method is often favored for use by the unskilled labor usually available on plantations in tropical countries.

An excellent summary of methods used in the important pyrethrum-growing areas throughout the world has been recorded by H. J. Holman (*12*). For accounts of techniques developed in the United

FIGURE 15.—Planting pyrethrum "splits"; Matucana, Peru.

States the reader may refer to the publications of Sievers,[8] Gnadinger (*6*, *7*), and Culbertson.[9]

Nurseries

In the United States it is the general practice to use seedling stocks grown in outdoor seedbeds or in greenhouses. A properly located outdoor seedbed ought to have a southern exposure, and it should be

[8] SIEVERS, A. F. PYRETHRUM: ITS CULTURE AND POSSIBILITIES AS A CROP IN THE UNITED STATES. U. S. Bur. Plant Indus. 7 pp., illus. [n. d.] [Mimeographed.]

[9] CULBERTSON, R. E. INSTRUCTIONS FOR PYRETHRUM GROWING. Rpt. to O. F. A. R. 7 pp., Belleville, Pa. Sept. 14, 1936. [Mimeographed; filed in T. C. B.]

prepared on a well-drained, neutral, or slightly alkaline sandy loam soil which has been spaded, or plowed, to a depth of at least 6 inches. Well-rotted manure or some commercial fertilizer, such as 2 or 3 pounds of a 4–8–4 mixture per 100 square feet of bed surface, may be incorporated in the soil if its fertility is low.

Weeds are likely to be a nuisance in the seedling nurseries; it is desirable therefore to choose a site on newly cleared ground or on freshly plowed sod land where the weed problem may be minimized. Steam sterilization, such as is sometimes practiced in preparing tobacco seedbeds, is a useful method of killing weed seeds in nursery beds where equipment is available. Before planting, the soil should be worked until finely pulverized and the surface made smooth. It is recommended that the beds be boxed in with side boards 12 to 14 inches high and that they be covered with cheap muslin to prevent wind drying of the soil during the germination period.

Between 40 and 50 percent of an average lot of heavy, well-cleaned, properly stored seed may be expected to germinate if planted within 3 years after harvest. The seeds are so small and light that nearly 30,000 of them are required to weigh an ounce. Even though half of them may germinate, a grower should not calculate on obtaining more than 3,000 to 5,000 thrifty seedlings worth transplanting to the field for each ounce of seed sown. Between 3 and 5 ounces of seed should be broadcast over 150 square feet of nursery bed for each acre of field planting desired. Some growers prefer to soak their seed in water for several hours previous to sowing in order to hasten germination. After broadcasting, the seed should be lightly raked into the soil or else covered to a depth of about an eighth of an inch with mixture of soil and sand; then the ground should be gently tamped or rolled.

The seed will germinate within 1 to 3 weeks, and during this period the soil should be kept damp and protected either by a muslin cover or a light mulch of straw or grass. If mulch is used, it should be removed as germination begins. Muslin need not be taken off until the plants are 0.5 to 1 inch in height. In temperate climates seed should be sown in the early spring or midsummer, and the plants ought to be 3 to 5 inches tall within 6 to 10 weeks. At this stage they may be dug up and set in the field or left in the nurseries over winter. Spring-sown plants should be transplanted by early summer. Those sown in midsummer are set out early the following spring. In the Tropics, where wet and dry seasons may be pronounced, seedlings should be sown in time to allow the transplants 3 or 4 months of rainy weather to become well established in the field before a period of prolonged drought is to be expected.

Field Planting

Pyrethrum grows well on soils ranging from sandy loams to clays; good drainage conditions are more important than a specific texture. Pot-culture work by Martin and Tattersfield (*21*) indicates that the total yields of flowers and of pyrethrin extracts are determined more by the inherent qualties of individual plants than by soil fertility. Gnadinger, Evans, and Corl (*7*) made field-plot studies of the effect of fertilizers on yields of flowers and pyrethrins and also concluded that there were no significant differences either as between controls and treated plots or between plots receiving various fertilizers, with the exception of slightly superior yields from plots receiving only muriate of potash. These investigations agree with the observations of growers that pyrethrum apparently yields satisfactorily even on relatively infertile soils, provided that good seed stocks are used and climatic conditions are of the best.

Thorough soil preparation, particularly to eliminate grasses and weeds from the field and to provide for rapid drainage, is important to successful culture. Often it is a practice to ridge the land and to set the transplants on the ridges. Recommended planting distances vary, but as a general rule the rows should be 2½ to 3 feet apart, and individual plants may be set at intervals of 12 to 15 inches in the rows. The planting itself can be done by hand with a dibble or with a mechanical planter, such as is used for setting tobacco and cabbage. It is important in successful pyrethrum culture to avoid covering the crowns of the plants with soil, both when they are being placed in the field and subsequently when the ground around them is cultivated to eliminate weeds. Soil spread over the crowns is likely to induce rotting, particularly if it becomes damp.

Insofar as climate is concerned, it has been demonstrated that pyrethrum is tolerant both of summer heat and winter frost. However, for maximum flower production, it should enter a winter dormant period, which in the Tropics may not be possible at altitudes of less than 6,500 feet. Field trials in Kenya indicate that near the Equator the minimum may be 7,000 feet. Once established, pyrethrum is relatively drought-resistant, but for maximum yields it must receive adequate rainfall or irrigation water during the period of flower formation.

Harvest

In the Tropics, even at high altitudes, it is the general habit of pyrethrum to blossom throughout the season of active growth, although there are certain times, particularly following extended rainy periods, when flowering becomes heavier than normal. In temperate climates, where the winter dormancy period is prolonged, most plants may come into flower at about the same time early the following summer. In sections of the United States where plantings have been made, the flowering takes place over a period of a few days, during which all but a small proportion of the blossoms are at the desired stage for harvesting. This makes mechanical picking feasible, and some methods reasonably successful under certain conditions have been devised. Entire plants may be cut off with mowing machines, or binders, and hauled to stationary mechanical strippers, which remove and separate the flower heads. Research workers *(28)* of the United States Department of Agriculture have developed a tractor- or horse-drawn field harvester (fig. 16) which has proved efficient in most of the trials made with it.

In the major commercial producing areas of the world hand picking by one means or another is the usual practice. Often the flowers are simply plucked singly by women and children (fig. 17). In some cases a scooplike box, fitted with a spike-toothed comb, may be used to strip flowers in the field. In Japan it is reported that plants are often cut with a sickle and the flowers removed by pulling the stems through a comb stripper mounted on the edge of a box.

The stage of blossom development at time of picking is important, particularly with respect to the keeping quality of the flowers during subsequent storage. The pyrethrin content of flowers increases up to the point where the majority of the disk florets open. After pollination, the pyrethrin content does not diminish, but the development of the ovaries causes a considerable increase in the weight of the floral head without a comparable increase in pyrethrins so that insecticidal quality gradually declines. More important than the small differences in pyrethrin content at various stages of floral development is the degree of its stability under storage conditions. Gnadinger et al. (7) have shown that immature and nearly mature flowers lose little pyrethrin during the first 60 days of storage but that mature flowers may lose as much as 13 percent.

FIGURE 16.—Mechanical pyrethrum picker developed by U. S. Department of Agriculture.

After harvesting, the flowers should be thoroughly dried either in the sun, in ventilated shelters, or in heated driers before they are baled for storage and shipment. A common belief is that pressure baling is necessary to prevent loss of pyrethrins in storage, but it has been shown that flowers packed under pressure of 16,000 pounds per square inch for a period of 263 days lost only slightly less pyrethrins than a comparable lot of loosely baled flowers (7).

PRODUCTION IN THE WESTERN HEMISPHERE

Brazil

Pyrethrin production in the Western Hemisphere has increased significantly in the past 5 years, with Brazil accounting for almost the entire amount. In 1946 total United States imports from all world sources reached 20,476,000 pounds, which was more than for any previous year. Brazil supplied slightly more than 9 percent of these imports. Indications are that the crop has now achieved real economic importance in sections of the State of Rio Grande do Sul, where it is reported that Sr. Rene Coulon first planted it at Caxias near Pôrto Alegre in 1890.[10] Pyrethrum was not grown commercially until local manufacturers of insect sprays created an active market for it in 1922.

Cultivation, which is now centered around the municipalities of Taquara, San Antonio, Caxias, Cangussú, São Lourenço, and Piratiní, is carried on chiefly by subsistence farmers who devote portions of their small landholdings to it as a supplementary cash crop. All the work involved is accomplished by hand or with hand tools; women and children do most of the picking. In 1942, when adult male labor received from 5 to 8 cruzeiros (25 to 40 cents) a day, dry pyrethrum flowers brought the growers 1 cruzeiro per kilo (about 2.25 cents a pound). This price was considered profitable by the farmers, who sold their small harvests to local country stores for cash or for trade goods advanced by the shopkeepers. Buyers, representing dealers in Pôrto Alegre and Pelotas, bought up these supplies from the country stores for processing in Brazil and for shipment abroad. Export values of pyrethrum containing 0.6 to 1.5 percent total pyrethrins averaged 7.60 cruzeiros per kilo (about 16 cents per pound) in 1943.

In Rio Grande do Sul, it is said, plants produce economically for from 6 to 10 years. Yields average about 400 kilos per hectare annually. Flowering begins in October and continues until May, but yields are particularly heavy during the months of November, December, and January. A second flush of blooms occurs during the latter part of March and early April. Some pyrethrum is also grown around Presidente Wenceslau in São Paulo.

Argentina

Pyrethrum culture in Argentina is gradually increasing, but up to 1943 less than 500 acres were estimated to have been in production.[11] Chief growing centers are in irrigated sections of the Provinces of Mendoza and San Juan and to a lesser extent in Catamarca and Salta. Yields vary between 600 and 1,200 pounds per acre, with 1,000 pounds being approximately the average on irrigated land. Pyrethrin content of the best grade flowers is said to be 1.2 to 1.25 percent. Laborers make between three and four hand pickings during the bloom season, although most of the crop is normally harvested in November. Since Argentina does not produce sufficient pyrethrum for its own insecticide manufacturers, acreages may be expected to increase at least until domestic requirements are satisfied.

Chile

Pyrethrum was first introduced into Chile by Yugoslav immigrants from the Dalmatian coast.[12] Although their experimental plantings

[10] WILLIAMS, U. H. THE PYRETHRUM INDUSTRY OF BRAZIL. U. S. Cons. Rpt. No. 239, 15 pp. Rio de Janeiro, Brazil. May 1943. [Hectographed.]

[11] STOOPS, DON. PYRETHRUM PRODUCTION IN ARGENTINA. U. S. Cons. Rpt. No. 30, 7 pp. Buenos Aires, Argentina. July 1943. [Hectographed.]

[12] WILSON, JAMES PARKER. CHILEAN PYRETHRUM PRODUCTION. U. S. Cons. Rpt. No. 290. 5 pp., illus. Santiago, Chile. Aug. 1943. [Hectographed.]

grew well, production never reached a commercial scale. It was not until 1939 that commercial production became a reality, when a Chilean, Sr. Luis Fontecilla, began to increase the acreage of pyrethrum on his medicinal-plant farm, Fundo Palermo, near the village of San Bernardo on the outskirts of Santiago. Even in 1943, the only grower was the firm Drogas Botánicas, S. A., organized by Sr. Fontecilla. In 1942 this firm harvested about 35,000 kilos from 40 hectares. Plants are propagated both with seeds and with splits. Principal harvest seasons are during October, March, and April, and plantings are at an altitude of about 3,500 feet. Locally the practice has been to grind an insecticidal powder from mixed flowers and floral stems.

Peru

Private landowners in Peru introduced pyrethrum in 1928. Beginning in 1933, extensive trials with pyrethrum were made by Peruvian agricultural experiment stations. Ten years later approximately 100 hectares were in commercial production at elevations ranging from 3,000 to 9,000 feet, principally in the Huancayo Valley of Junin Province. Most of the present plantings are on the small landholdings of subsistence-farming Indians who have chosen the crop as a means of earning a little cash. Plants are propagated both by seed and by splits. The life of the average planting is estimated at 6 years, and yields are estimated at approximately 500 kilos per hectare after the first season. At higher altitudes the pyrethrin content is said to be usually more than 1.2 percent.[13]

FIGURE 17.—Harvesting pyrethrum flowers at Matucana, Peru.

[13] MARTIN, WILLIAM. PYRETHRUM SITUATION IN PERU. 3 pp. [Hectographed report, filed in T. C. B., O. F. A. R., sent in by Benj. J. Birdsall, Amer. Embassy, Lima, Peru, April 13, 1943.]

Ecuador

Statements are made that pyrethrum was not grown in Ecuador prior to 1940.[14] At that time, samples of seed were secured and planted on the grounds of the agricultural experiment stations at Alausí and Ambato at elevations of 2,333 and 2,555 meters, respectively. The plants grew satisfactorily, and flowers from Alausí analyzed 1.1 percent total pyrethrins. In 1943, about 60 acres were planted for commercial production in response to encouragement and assistance by the Estación Experimental Agrícola del Ecuador. Additional experimental plantings were established at Patate, Ibarra, Pelileo, Pillaro, Quito, Calacali, Aloag, Riobamba, Otavalo, Cayambe, Latacunga, Salcedo, Chambo, and Tunchi.

Central America

Pyrethrum has been grown experimentally in Costa Rica, El Salvador, and Guatemala, but not until 1944 was an effort made to cultivate the crop on a commercial scale.[15] In that year Stephen White of the United States Board of Economic Warfare distributed seedlings to 10 plantation owners in Guatemala. By December 1945, about 105 acres were in production. Yield data taken on 19 acres of four farms during the first year of production indicated an average of 389 pounds per acre. The first commercial shipments made in 1945 assayed 0.83 to 0.89 percent pyrethrins after 9 months of storage, but analysis of flowers taken from all pyrethrum fields in Guatemala showed a range in total pyrethrin content of 0.79 to 2.13 percent and an average of 1.22 percent. Altitudes at which the crop is grown vary from 5,000 feet near Antigua to 8,500 feet near Palestina.

Other pyrethrum-producing farms are located near Chicacao, at 7,200 feet; Tecpán, at 7,500 feet; Fraijanes at 6,000 feet; Quezaltenango at 8,000 feet; and Amatitlán, at 5,500 feet. At the present time the Instituto Agropecuario Nacional is engaged in making selections of superior strains for Guatemala. Most Guatemalan pyrethrum is sun- or stove-dried, but one grower at Tecpán began in 1946 to use infrared lamps after preliminary sun drying.

Haiti

Haiti has become the most recent exporter of pyrethrum flowers in the Western Hemisphere. With the assistance of the United States Foreign Economic Administration, trial plantings were begun in 1942 at Haitian agricultural experiment stations at Savanne Zombie and Oriani at altitudes of 4,500 and 5,000 feet. In 1945, United States private interests in cooperation with the Haitian-American Development Corp. established a trial planting of special Tennessee varieties at Gros Cheval, 5,025 feet in altitude. Experimental plantings at Oriani produced flowers assaying 1.2 percent pyrethrin content. In 1945, commercial planting was begun, and a year later the first exports, totaling 1,268 pounds, were made to the United States.

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[14] CULBERTSON, R. E. PYRETHRUM IN ECUADOR. Rpt. to O. F. A. R., 9 pp., illus. [n. p.] Jan. 7, 1944. [Hectographed; filed in T. C. B., O. F. A. R.]

[15] WHITE, STEPHEN S. PYRETHRUM PRODUCTION IN GUATEMALA. Rpt. to U. S. Com. Co. 24 pp., illus. [n. p.] [n. d.] [Hectographed; filed in T. C. B., O. F. A. R.]

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