Progress Report on

the Cooperative Hevea Rubber Development Program in Latin America

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Progress Report on the Cooperative Hevea Rubber Development in Latin America[1]

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THE COOPERATIVE RUBBER PROJECT, 1940-54

This report covers significant results of the long-term cooperative rubber research and development project between the United States Department of Agriculture and tropical America. Developing a tree crop to specifications is a slow and unspectacular undertaking compared with the developing of new chemical products, but the end result can be just as far reaching. Awareness of its progress is equally important.

Begun in June 1940, the hevea program continued uninterruptedly for 14 years in cooperation with interested Latin American governments, private companies, and growers. Only through the unfaltering support and encouragement of these cooperators has a sound basis finally been laid for a commercial industry. Although many problems remain to be solved, the progress already achieved should interest all those concerned with long-range strategic and economic planning for the Western Hemisphere, as well as with permanent hevea rubber production anywhere.

On July 1, 1954, field personnel and administration of this project were transferred to the Foreign Operations Administration. Therefore, the summary is limited to the 14-year period ending June 30, 1954, during which the project was directed by the United States Department of Agriculture.

DEVELOPMENT OF A POINT IV TYPE OF COOPERATIVE PROGRAM

On June 22, 1940, the Congress of the United States passed an act authorizing the development of a rubber development project in the Western Hemisphere. As a result, cooperative agreements between the United States Department of Agriculture and 15 tropical American countries were signed to provide for initial land surveys. Subsequent research and development projects were undertaken in 13 of the countries. The agreements provided cooperation not only with the United States but, more important, among the Latin American coun-

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[2] We wish to acknowledge our indebtedness to Marion W. Parker, Forrest G. Bell, and William Mackinnon for invaluable aid in reviewing this report. For certain sections also, assistance has been given by the specialists in the various countries: Howard F. Allard, Arthur W. Bechtel, Lawrence A. Beery, Jr., John B. Carpenter, Harry C. Haines, Ernest P. Imle, Michael H. Langford, J. Forres O'Donnal, and Raymond E. Stadelman.

tries to facilitate exchange of plant materials and research results, as well as reciprocal inspection of progress.

From 1942 to 1949, United States participation in the project was financed through foreign cooperation authorizations to the Department of State, and, from 1950 to 1954, through the successive Mutual Security Acts. The appropriated funds were then allotted to the United States Department of Agriculture. Congress appropriated around $300,000 annually for this project until the advent of the Point IV program in 1951; since then, this sum has nearly been doubled.

By its origin, scope, type of organization, and long-term technical guidance method of operation, the rubber development program was the pioneer agricultural technical assistance project in Latin America. However, in comparison with the recent much expanded extension programs for food and other crop developments, it is not representative, because (1) rubber cultivation was a new enterprise for the hemisphere, and (2) the recommended "sharing of knowledge" by the technicians was possible only to a limited extent. This knowledge had first to be gained through joint experimentation and intensive regional research.

PROBLEMS IN DEVELOPING THE RUBBER INDUSTRY

During the early part of the cooperative program, it was realized that the necessary research and practical experimentation to adapt Far Eastern experience and to develop new methods for successful rubber production in the Western Hemisphere would require approximately 10 years. This has proved true.

Initial plantings of hevea rubbertrees (*Hevea brasiliensis* (Willd. ex A. Juss.) Muell. Arg.) from improved Eastern strains by governmental and private agencies during the early 1940's encountered unexpected difficulties when it was discovered that these trees were not resistant to the South American leaf blight (caused by the fungus *Dothidella ulei* P. Henn.). Therefore, the tree needed to be made over—"tailored," so to speak—to make it resistant as well as high yielding. Also, the standard extension methods used to encourage rubber plantings on small farms gave less than 50-percent success. Farmers had no appreciation of the value of the rubbertree. Their necessary preoccupation with the immediate means for a livelihood made them neglect these small but strange tree plantings, although they had been told they would yield a cash crop after 5 or 6 years' work.

ESTABLISHMENT OF REGIONAL RUBBER EXPERIMENT STATIONS

In tackling the problems of rubber production in Latin America, the United States Department of Agriculture adopted much the same pattern and techniques that had been most successful and economical with crop problems within the United States. Regional problems are solved on a regional basis at some central station, mainly at Federal expense, and the States cooperate by adapting the results to local conditions or work on specific and limited problems, mainly at State expense.

Application of this principle to Latin America has been generally accepted by the cooperating countries as fulfilling the Department of Agriculture's commitments under the bilateral agreements involving this specialized regional research for the benefit of all. The alternative was to disperse personnel on regional projects among the individual countries in order that operating costs might be borne by each cooperating government. This would require more scientists and duplication of facilities and would hamper coordination and efficiency, thus resulting in greater cost to the United States than the operating cost of regional stations.

As outlined in previous reports (*12*, *13*, *14*, *66*),[3] the United States Department of Agriculture, in cooperation with 13 tropical American countries, established and maintained 3 regional experiment stations—Turrialba and Los Diamantes, Costa Rica; Entre Rios, Guatemala; and Marfranc, Haiti. The United States assigned research and advisory personnel to stations or development projects maintained by the other cooperating governments (fig. 1). Location of the regional stations was dictated by biological considerations, but was dependent on the requisite invitation and assurance of at least some participation by the host government. Figure 2 shows the office-laboratory building of the regional station near Turrialba, Costa Rica.

These regional stations in recent years have played an increasing role in training of nationals from all the cooperating countries. The regional station in Costa Rica is directly adjacent to the Inter-American Institute of Agriculture Sciences, with which a working relationship for student training in rubber has been very successful. Station scientists also gave lectures at the Institute.

One important function of the Costa Rica regional station has been the training and orientation on rubber of students and agronomists from other countries. A total of 17 trainees from 7 Latin American countries have spent from 1 month to a year on training assignments to Turrialba. In addition, agricultural and other officials from practically all other tropical American countries have at one time or another visited the station. Representatives of rubber plantation companies, research institutes, and governments of Africa and Southeast Asia were also among the visitors.

Nearly all newly appointed United States technicians have spent from a few days to several months in Costa Rica, familiarizing themselves with all phases of rubber production and processing before continuing on to their assignments in other cooperating countries. Many of them have returned later for further study.

PIONEER WORK OF THE FORD AND GOODYEAR COMPANIES

The pioneer rubber plantations, established by the Ford Motor Co. in 1928 at Fordlandia, Brazil, and of the Goodyear Rubber Plantations Co. in 1935 in Costa Rica and Panama, contributed invaluable material and experience in establishing the rubber industry in the Western Hemisphere (*2*, *11*, *32*, *60*, *63*). These plantations were badly damaged

[3] Italic numbers in parentheses refer to Literature Cited, p. 741.

FIGURE 1.—Research centers and cooperative projects in Latin America.

by the South American leaf blight. Control of this disease was achieved by persistent teamwork of the company technicians with those of the United States Department of Agriculture, representing a notable example of industry-government cooperation. This is emphasized in a recent booklet (*25*) by the Goodyear Tire & Rubber Co.

During 1933–40, the blight devastated the Fordlandia plantation, comprising 7,500 acres that had been planted mostly with unselected seedling trees. The seed for these had been collected from jungle trees along the Tapajoz River, on which the plantation was located. However, scattered trees were observed to retain their foliage after the epidemic, and thus were either resistant or had escaped the disease. Such trees usually had originated from seed or jungle budwood collec-

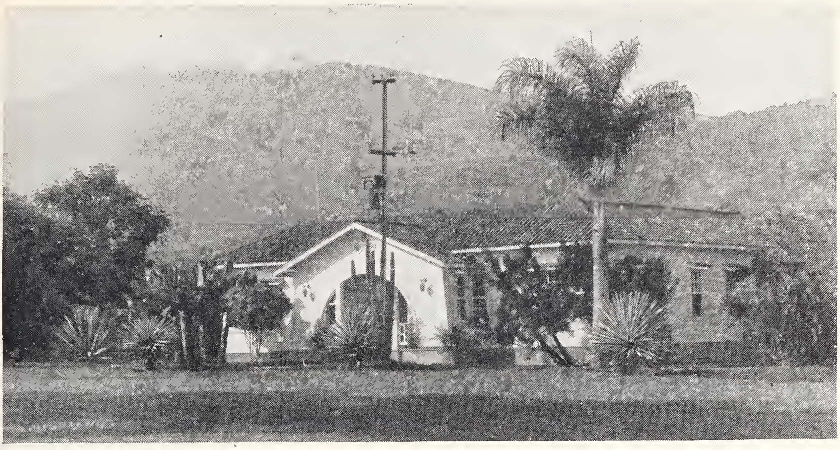

FIGURE 2.—Office and laboratory of the United States Department of Agriculture at the cooperative rubber plant field station near Turrialba, Costa Rica.

tions from other parts of the Amazon Valley. Many of the apparently resistant trees were established as clones and were used in 1936 for some preliminary crownbudding trials.

On the Goodyear Allweather estate in Panama, which had been planted almost entirely with Eastern clones, the experience was the same. However, certain limited areas planted with seed from Belem, Brazil, and certain selections from other Amazonian districts showed striking resistance.

After the blight had ruined the plantings at Fordlandia, a second plantation, Belterra, was started in 1934, 30 miles south of Santarem at the mouth of the Tapajoz River. It was hoped that the well-aerated plateau on which Belterra was situated would escape serious damage from the leaf blight. Belterra did escape during the first 4 to 5 years, but this was only because the trees had not generally reached the age for "wintering," or annual leaf change, when the predominance of highly susceptible young leaves makes conditions most conducive for epidemic spread of the disease.

In 1941 and 1942, following 3 years of devastating leaf blight epidemics at the Belterra estate, crownbudding with resistant clones was urgently recommended by L. A. Beery, Jr., a representative of the United States Department of Agriculture, who was stationed at Belterra on the cooperative breeding program.

The Ford management then undertook the stupendous task involving the decapitation, or pollarding, at a height of about 7 feet, of more than 2,000,000 trees, many of which were nearing tapping size. Some 600 laborers were used, and about 200 of these became skilled budders. Sprouts emerging from near the top of the sawed-off trunks had to be protected by spraying until of sufficient size for budding with the resistant material. By the end of 1945, the job was completed. Necessary pruning and care of the emerging resistant shoots encouraged development of new crowns of healthy green foliage. Nevertheless, there was a delay of 2 to 3 years for this development before the plantation could be brought into production. Figure 3 shows representative

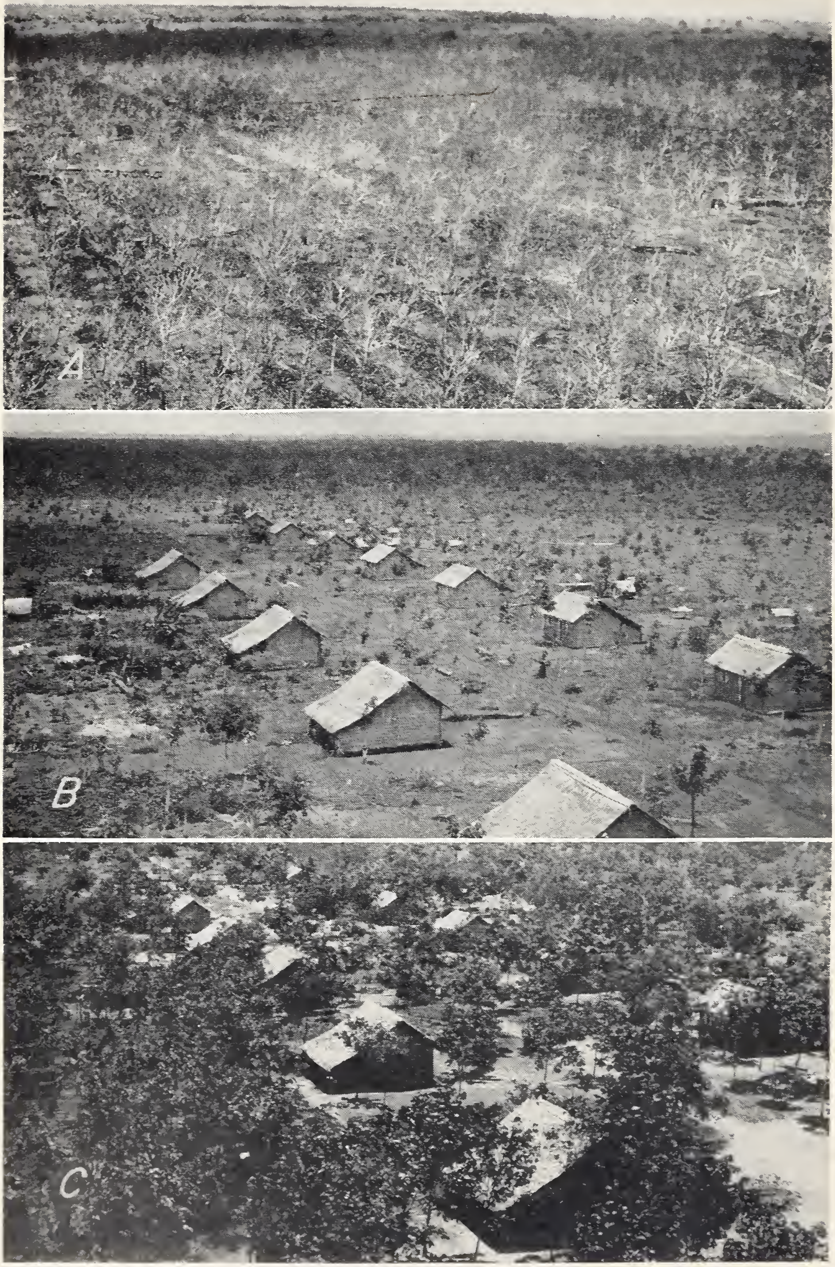

FIGURE 3.—Restoring a devastated plantation. Typical parts of the 16,900-acre Belterra plantation in Brazil originally basebudded with high-yielding susceptible Eastern clones: *A*, In 1942 trees repeatedly defoliated and almost killed by leaf blight; *B*, in 1945 the same trees topbudded with resistant clones; *C*, in 1947 the same trees as in *B* after 2 additional years of growth. Commercial tapping began in 1948.

areas of the Belterra plantation, illustrating successful restoration of the plantation by crownbudding.

CONTROLLING SOUTH AMERICAN LEAF BLIGHT

Earlier investigations of the South American leaf blight (*62*), a limiting factor in hevea culture in tropical America, formed the basis for a double-pronged attack—control of the disease by fungicides and the development of resistant clones for topbudding and for resistant varieties.

Using modern techniques of plant pathology, Langford (*35*), cooperating in 1940 with the Goodyear Rubber Plantations Co. in Panama, quickly refuted the earlier contentions that leaf blight could not be controlled by spraying with suitable fungicides. However, spraying was too expensive for tall plantation trees, so this method alone did not solve the problem of utilizing the high-yielding, but very susceptible, clones that had been introduced from the Far East.

Developing the 3-Component Tree

The second line of attack involved development of the double-budding procedure (*63*, *87*) by which the 3-component tree was formed, and this procedure is still the chief reliance for commercial planting in most cooperating countries of Latin America. This type of tree consists of (1) the usual seedling rootstock, which is (2) budgrafted near the ground with the high-yielding Eastern strain (the so-called "panel clone"), which, in turn, is (3) topbudded, or crownbudded, at a height of about 8 feet (2.4 meters) with a bud from a blight-resistant strain (called the crown or top clone). This, then, produces a plantation tree with the usual vigorous root system, a high-yielding trunk, and a resistant crown.

Crownbudding is an old horticultural practice in the fruit tree industry. Its trial on hevea, according to De Vries (*24*), was first suggested by Cramer as a means for controlling powdery mildew in Java. In their selection work, Maas, Van Heusden, and Ferwerda, according to Lasschuit and Vollema (*46*), had discovered that the rather low-yielding clone LCB 870 was resistant to powdery mildew. Therefore, in 1928, 100 seedling trees were budded at a height of 2 meters (6.6 feet) with this clone. During the following year a number of ordinary basebudded trees of various clones were "highbudded" with LCB 870. The purpose in budding at different heights was to learn what effect the mildew-resistant crown would have on growth and yield of the panel clone.

These experiments received little subsequent attention after control of mildew was effectively achieved by sulfur dusting. However, in Ceylon, where mildew was less easily controlled and where the clone LCB 870 showed such striking resistance, the subject of crownbudding has recently received much attention (*101*). Accordingly, Lasschuit and Vollema (*46*) have searched out and published the yield data for the period of 1932–35 on the 100 topbudded seedling trees in Java. The data, comparing 3 heights of tapping cut, showed that the low-yielding LCB 870 exerted a depressing influence on yield when the cut was 100 cm. but not when it was 150 cm. below the union. Therefore, they recommended that topbudding be at a height of 2.5 meters in order that the tapping panel, extending 1 meter from ground level, would not be affected.

In the Western Hemisphere, crownbudding was first tried in 1936 by J. R. Weir, adviser on the Fordlandia estate in Brazil. Some 10 acres of ordinary seedlings and Eastern clonal trees were topbudded with various selections of *Hevea guianensis* Aubl., some of which have since proved rather susceptible to South American leaf blight. These initial experiments—at Fordlandia in 1936 and at Belterra in 1937—were described by Johnston (*2*) and Sorensen (*87*). One of the oldest

FIGURE 4.—One of the first trees of Eastern clones topbudded with a leaf-blight-resistant clone (F 5080 selection from *Hevea guianensis*) on the Belterra plantation in Brazil. Many of the remaining 8-year-old trees were either killed or seriously retarded by the blight.

topbudded trees surrounded by unbudded trees of the same age at Belterra is shown in figure 4. These striking results were the basis for the wholesale adoption, in the early 1940's, of topbudding on the Belterra plantation of the Ford Motor Co. and on the Goodyear plantations in Central America.

Topbudded Trees Feasible as a Nursery Product

Imle and coworkers (*29, 31*) at the Costa Rica regional station have worked out nursery practices and budding procedures that make the 3-component tree commercially feasible as a nursery product ready for setting in the field. Both basebudding and topbudding are performed in the nursery, and the time-saving feature is the placement of the top bud into the green stem of the uppermost leaf flush of the 7- to 8-foot high panel clone. The tree remains in place until the substituted top has produced 2 leaf flushes, after which the top flush and any lower leaves are cut off before transplanting. A period of

2 to 2½ years is required from original seeding in nurseries to transplanting of the finished 3-component tree to the field. Its cost under experiment station conditions, including paper wrapping, has been about 25 cents (U. S.) per tree, but there is a saving of at least 1 year of field maintenance as compared with transplanting the tree at an earlier stage of its development.

This type of planting material, produced in central nurseries, is especially suitable for distribution to small growers who lack the knowledge and skill to do the necessary budding themselves. They need only to plant and care for the trees for 5 to 6 years until they are tappable. At that time, further guidance is required to instruct in tapping techniques and the preparation of marketable rubber.

High-yielding Eastern clonal seedlings have also been topbudded in the nursery, as given above; their total cost, including cost of seed, has been less than 3 cents per tree. A period of only 1 to 1½ years is required to produce a topbudded clonal seedling in the nursery. They are more variable than basebudded trees, however, and must be planted at much greater field density to permit more extensive selective thinning on the basis of yield.

According to studies by W. Mackinnon, plantation management adviser of the United States Department of Agriculture, topbudded clonal seedling trees should be the predominant type of material distributed to farmers of small acreages during the next few years.

Neither the high-yielding Eastern clonal seedlings nor basebudded trees can be used in porous soils or in districts subject to intensive dry periods. Here, budded stumps or low-topped clonal seedlings are used, and these may have to be sprayed in the field to control leaf blight until they reach crownbudding size.

Other Improvements Reduce Commercial Costs

The resistant tops of most commercial areas of 3-component trees planted in 1943 to 1946 in the various countries are now producing abundant crops of seed. These seed, when sown in nurseries for production of rootstocks, give plants with sufficient resistance to leaf blight and do not require spraying. Nearly all cooperating countries now have a local source of resistant seed for such nursery use. Only the budwood multiplication gardens and budgrafts of the Eastern clones (prior to topbudding) still require spraying against leaf blight. Thus, the costs of production of plant material and its field establishment have been greatly reduced and the operations have been somewhat simplified. Despite this, the procedures are still too complicated for the small farmer, and this emphasizes the role of the plant multiplication and distribution centers now operating in the larger countries for expansion of rubber acreage.

Development of Clonal Material for Grafting

Resistant Crown Clones

Of the dozens of "resistant" selections made at Fordlandia (p. 5), some proved to be "escapes," while others were not sufficiently resistant to South American leaf blight for commercial use. Comparative resistance tests by Langford (*36*, *37*) at the regional station at Turrialba, Costa Rica, have enabled selection of a half dozen or more for use in the cooperating countries. Certain monoclone line tests at Belterra had also enabled the selection of those top clones that combine necessary resistance with suitable vigor, crown type, resistance to wind breakage, and compatibility with the panel, or trunk, clones recommended for commercial planting.

Since 1945 the list has been modified repeatedly, as data from certain countries or districts showed too great susceptibility of certain selections. Langford (*29*) ascribed this variation in susceptibility to differences in the virulence of the fungus in different areas.

Office reports by M. H. Langford at Turrialba, Costa Rica, and Karl D. Butler, formerly stationed at Belem, Brazil, give the contrasts in reaction of large populations of nursery seedlings to the leaf blight in Costa Rica and Brazil (fig. 5). These data were obtained in 1941 from some of the earliest nurseries in both localities.

In later years, Langford mentions that the behavior of specific selections in smaller nurseries of the respective seed origins indicated some shift in the fungus population. The most striking change occurred in the nurseries at Tingo Maria, Peru. The first nursery was planted with seed from a seedling plantation of the Far Eastern, or "Wickham strain," in Central America. As shown in figure 5, this strain was highly susceptible to leaf blight.

Adjacent to this nursery at Tingo Maria, budded stumps of various Eastern clones were established; and next to this nursery, seed from the local jungle species (*Hevea guianensis* Aubl. var. *lutea* (Spruce ex Benth.) Ducke & Schultes) was planted in a few nursery beds. During the first year blight spread from the jungle trees and almost defoliated the seedlings of the *guianensis* species, while both clonal and seedling plants of the Wickham strain were not noticeably damaged. However, in subsequent years seedlings of the Wickham strain showed increasing damage, and fungicidal spraying was required to grow seedlings to budding size. This indicated a definite shift in the fungus population toward greater virulence on this introduced material.

In general, seed and budwood collections of *Hevea* (regardless of species) show greatest susceptibility when first tested in the same locality where the strains of both fungus and host were indigenous. Therefore, all top clones recommended for commercial use must first be tested for resistance in all infested commercial areas, including the principal Amazonian districts.

Hybrid Crown Clones

During the course of the breeding program at Belterra, Brazil, many vigorous but generally low-yielding hybrid clones, highly resistant to the South American leaf blight, were produced. Outstanding has been the progeny from interspecific crosses between the plantation species (*Hevea brasiliensis*) and certain highly resistant jungle selections (*H. benthamiana* Muell. Arg.). Many of these F_1 hybrids were used in 1945 to topbud blocks 403 and 408 at Belterra. The majority of trees under this polyclonal canopy, as well as those topbudded in 1948 at the Costa Rica station with a selection of these hybrids, have made exceptional growth and can probably be taken into tapping nearly a year earlier than has been possible with the pure *brasiliensis* crown clones previously used at Belterra and elsewhere.

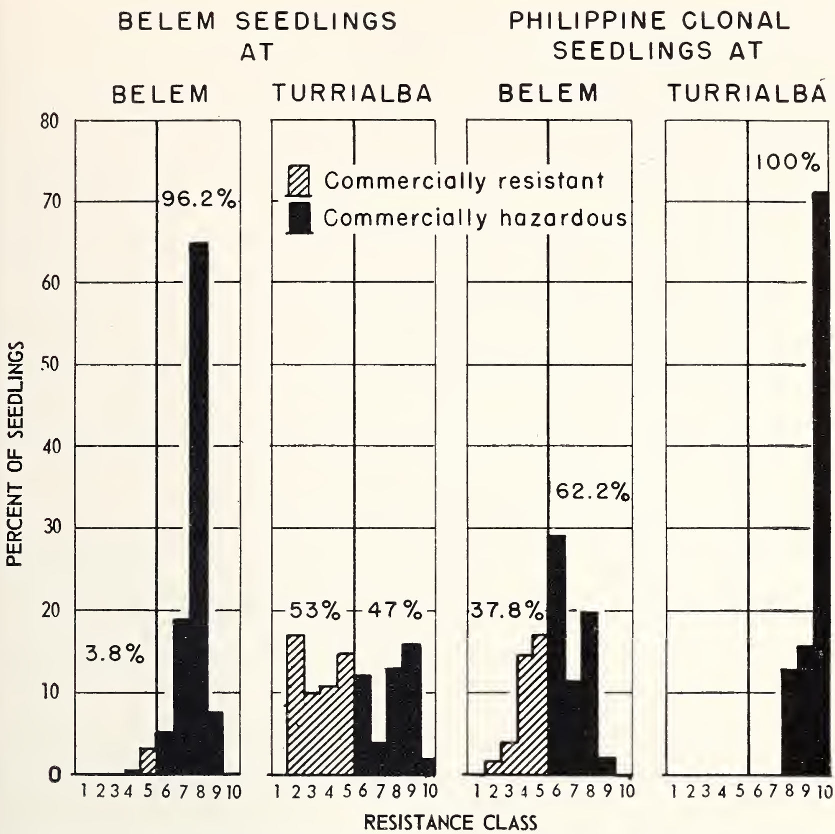

FIGURE 5.—Locality differences in virulence of the leaf blight fungus on each of two groups of nursery seedlings from different sources.

Not only are many of these F_1 hybrids nearly immune to leaf blight, but some of them are highly resistant to phytophthora leaf fall, according to studies by W. E. Manis (*49*) and J. B. Carpenter (*20*) in Costa Rica.

Pending completion of current studies, Brazilian and United States workers tentatively selected 8 hybrid clones at Belterra in October 1953 for immediate use as crown clones in the expanding rubber plantings in several parts of Brazil. This list probably best combined all essential characteristics for a polyclonal canopy, although a secondary list of 8 clones, either slightly less suitable or less well known, was also recommended. Similar lists are currently recommended in other countries. Those for Costa Rica and climatically similar areas where phytophthora leaf fall, as well as South American leaf blight, is a serious hazard are different. This is also true for Peru, where resistance to target spot must be combined with resistance to leaf blight in their crown clones. Wherever resistance to more than one disease is required, the presently recommended resistant clones may represent a compromise on other desirable characters, at least during the present stage of the selection work.

High-Yielding Clonal Seedlings

The Goodyear Rubber Plantations Co. has demonstrated the value of crownbudded clonal seedlings on its Costa Rica estate. Families of Eastern clonal seedlings were obtained from open-pollinated crossing of Tjir 1 × Tjir 16 and other combinations on its Philippine estate. The seed was sprouted, protected by spraying, and later topbudded at a height of 6 to 7 feet, as described above for the 3-component tree. Yield records after several years of tapping demonstrate rubber production to be fully equal to that of the same families of untopbudded seedlings on the company's Philippine and Sumatra plantations.

High-yielding Eastern clonal seed has recently become available in the Western Hemisphere and is much in demand by small growers in areas not subject to heavy leaf blight damage. Several plantations on the west coast of Guatemala where crownbudding is not required for leaf blight control, as well as similar areas in the blight-free countries Haiti and the Dominican Republic, constitute the present source of this seed.

Disease-Resistant Clonal Seedlings

While many small-farm plantings are already being established with the susceptible Eastern material, furnished by stations or pilot plantation centers along with continuous supervision, it seems generally agreed that resistant clonal seed will be required for any rapid expansion. Such seed would be available during the next 6 to 10 years, if the breeding program is continued.

Extensive seed gardens for production of the second backcross to Eastern clones (BC_2 progeny) are now being established in several countries. It is hoped that such seedling progenies may approach or equal minimum Eastern clonal rubber yields. However, about 50 percent of the seedlings (like the BC_1) will undoubtedly prove susceptible to the South American leaf blight, so only the resistant seedlings should be transplanted to the field. Still higher yielding resistant seed may be obtained later should the third backcross (BC_3) generation inherit a similarly high resistance, and further gardens be established for commercial seed production.

BREEDING FOR DISEASE-RESISTANT VARIETIES AND SUPERIOR YIELD

Objectives

Expansion of low-cost native or small-farm type of rubber production requires simple planting techniques with minimum subsequent attention by the farmer. He usually has no time, inclination, or competence for the exacting and complicated procedures of budgrafting 3-component or even 2-component trees. These are now produced in central nurseries and distributed to him, or specially trained extension workers do the budding, especially the crownbudding, in his own garden. At present, therefore, the small grower is dependent upon government agencies for his planting material and essential services to get started or to expand his present acreage of rubber.

Ideally, only 5 to 10 acres of his 20- to 50-acre farm, especially in colonization projects, should be planted to rubbertrees. Nevertheless, when once established and brought into production, rubber may assure a steady and significant source of cash income for the family over the following 20 to 30 years.

The ultimate aim of the hevea breeder is to provide the small farmer with varieties that can be grown from seed and require no more attention than is customarily devoted to familiar tree crops, such as coffee and cacao. Obviously this is a long-period undertaking, but the intervening years are serving to demonstrate the value of this new crop, through nucleus plantations and carefully selected and supervised small-farm plantings, using the presently available double-budded planting stock. A surprising demand for budded or double-budded trees already has developed in several of the cooperating countries where small growers are now tapping their few hundred trees and marketing the rubber. Therefore, it would appear that the present intermediate stage in the breeding and selection program to produce the "ultimate tree" may enable significant small-farm expansion of commercial plantings.

Successive Steps in Breeding Program

(1) Select disease-resistant, plantation or jungle seedling trees of *Hevea brasiliensis* and other *Hevea* species and establish them as budgrafted clones.

(2) Use the budgrafted clones to crownbud the high-yielding but susceptible Eastern clones for commercial rubber production, and, incidentally, to furnish a local supply of resistant seed for nursery rootstocks.

(3) Cross the better producing disease-resistant selections with high-yielding Eastern clones, and select resistant hybrids, a few of which may approach or equal the Eastern parent in yield. Propagate these, in turn by basebudding on seedlings produced under (2), and test for commercial suitability.

(4) Intercross selections from (3) to obtain second-generation hybrids, thus establishing clones for commercial use that combine resistance and superior yield.

(5) Backcross selections from (3) to the Eastern parent or outcross to other Eastern clones. The seedling progenies from this first backcross should contain many selections of commercial promise for use as clones. Certain BC_1 progenies containing 25 percent *H. benthamiana* "blood" have shown as high as 50-percent resistance to leaf blight.

(6) Further backcrossing or outcrossing of selections from (5) to Eastern clones will give the second-backcross generation, with still greater opportunity for selecting high-yielding clones that retain resistance to South American leaf blight and other diseases.

It is hoped, considering its lineage, that at least 50 percent of the seedlings of this second-backcross generation will be resistant and of commercial grade suitable for direct use by small farmers without any budgrafting procedures.

Steps 1 to 5, inclusive, have been taken in Brazil, beginning in 1937 with the pioneer work of the Ford Motor Co. The breeding work was carried on from 1942 to 1945 as a 3-way cooperation between the Ford Motor Co., the Instituto Agronomico do Norte, and the United States

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Department of Agriculture. The Ford Motor Co. disposed of its Brazilian plantations in January 1946, and since that time the other 2 agencies have continued the program. Throughout this period, resistant Ford selections (F) and Ford crosses (FX) and Brazilian selections (IAN) have been distributed to other cooperating countries and established in breeding gardens, where conditions for carrying out parts of the program are more favorable than the Amazon areas.

In a recent publication by Tysdal and Rands (*93*), these successive steps have been described in more detail. After 15 years of breeding work in this hemisphere, the program has reached step 6 above. This step was taken in the spring of 1953 by the planting of gardens to produce, after another 3 to 5 years, commercial BC_2, or second generation, seed that may be suitable for small growers.

Although specific lines of breeding have progressed to the above advanced stages, each of the earlier steps is now being repeated to obtain more valuable parent material. This is characteristic of most crop-breeding research (but it is of special importance with hevea, where nearly 10 years are required for full evaluation of each breeding generation. Relative disease resistance of new progenies may be ascertained in 1 or 2 years, but, unfortunately, there is no reliable method of forecasting mature rubber yields from tests on such juvenile material.

The locale for further improvement of hevea must necessarily pass from Southeast Asia to Latin America, where all the species and myriad forms of the genus *Hevea* are native and where also, fortunately, one of the principal hazards, South American leaf blight, is still confined. A proper evaluation of indigenous materials and their use in breeding programs should not only achieve full domestication of the Para rubbertree, but increase its yield and adaptability beyond anything thus far obtained from the limited representation of the single species (*H. brasiliensis*) that has been available in the Far East. Research workers in Malaya, long alert to this situation, have arranged informal cooperation with Latin American countries and the United States Department of Agriculture to participate in this breeding program. Since the new seedling progenies produced in the East would have to be sent to Latin America for resistance tests, a sharing of costs and any valuable selections obtained will be of mutual benefit to both hemispheres. The following sections summarize the above and several other lines of research that are basic to this long-term objective of the breeding program.

The Hevea Rubbertree

Early Explorations and Research

Far Eastern workers early recognized that their "Wickham *Hevea*," although extremely variable in morphological characters and yield, had come only from one small district on the lower Tapajoz River in Brazil, and therefore might not contain all the hereditary factors for the best plantation tree. Furthermore, explorers and taxonomists had described several different, and allegedly superior, regional strains or varieties of *H. brasiliensis*, as well as more than a dozen other species from the Amazon region. Thus, in 1913, the late P. J. S. Cramer undertook an expedition from Java to the Guianas and Brazil and obtained several seed collections of *H. brasiliensis* and 4 other species. The *H. benthamiana*, introduced as seedling plants, failed to survive. These are all described in the Dutch "Handboek" of 1921 (*1*).

Apparently none of these or subsequent collections by others contributed to the later breeding program that developed the high-yielding Eastern clones. The surviving other species were inferior in rubber quality. Apparently the Cramer and subsequent *brasiliensis* introductions were never multiplied under isolation to adequate seedling populations for individual selection, a stage already reached with the Wickham strain, preparatory to the development of budgrafted clones.

Rubber survey expeditions were sent to the Amazon basin in 1923 and 1924 by the United States Department of Agriculture and the United States Department of Commerce. La Rue (*43*) has summarized the botanical studies, showing the extreme variability and importance of differences between regional types of *H. brasiliensis*, especially between those of the lower river and southern highland types. At the same time, variation in susceptibility to South American leaf blight was reported by Rands (*62*), who surveyed the ruined Guiana plantations, some areas of which had been started with seed from the lower Amazon Valley of Brazil.

The variability of the species was taken into account in the establishment of the Fordlandia plantation in Brazil. That pioneer enterprise of 7,500 acres, begun in 1928 and completed in 1934, was planted mostly with seed from the Tapajoz forests in which it was located. However, with the advice of J. R. Weir, part of the plantation was planted with seed collected in regions of the lower Amazon, the Rio Negro, and the Acre Territory. Regional strains of other species were assembled.[4]

The devastating epidemics of South American leaf blight that afflicted the Fordlandia plantation in 1935 later revealed highly resistant trees only among those collections from the several distant parts of the Amazon Valley. In general, trees of Tapajoz origin showed little or no resistance, and this was especially true for some 52 high-yielding Eastern clones (also of Tapajoz derivation) that J. R. Weir had brought from Southeast Asia in 1934.

Hundreds of apparently resistant individuals were noted in the miscellaneous seedling areas at Fordlandia, and these were propagated for further study. Many were subsequently used for crownbudding the Belterra plantation that had been planted with the susceptible Eastern clones. At the beginning of the present cooperative program, the large assemblage of valuable material at Fordlandia was made available to the cooperating agencies by the Ford Motor Co.

The Ford Motor Co. expeditions, led by Townsend, obtained budwood from a considerable number of outstanding jungle trees. When tested as clones at Belterra, the resistant selections of *H. brasiliensis* from the Acre Territory were mostly slow-growing and low in yield. Some excellent types of several other species were obtained—particularly of *H. benthamiana* (4000 series in the Ford numbering system

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[4] The writers are indebted to C. H. T. Townsend, Jr., a former technician of the Ford Motor Co., for early data on the Fordlandia and Belterra plantations.

for identifying selections), *H. guianensis* (5000 series), and *H. spruceana* (Benth.) Muell. Arg. (6000 series)—which have been used in the breeding program.

Recent Explorations and Taxonomic Studies

The variability in resistance to South American leaf blight and other characters among the regional collections of *Hevea brasiliensis*, as well as of the other species observed in 1940–42 on the two Ford plantations, emphasized more than ever the importance of further jungle explorations and collections for the benefit of the future plantation industry. Accordingly, from 1942 to 1953, under agreements with Brazil, Colombia, and Peru, one or more taxonomists of the United States Department of Agriculture, cooperating with local scientists, worked continuously in the principal Amazonian regions of those countries. The objective was to make a detailed taxonomic and ecological study of the poorly defined entities of the genus *Hevea* and closely related forms in their native habitats and to collect both seed and budwood from representative and elite individuals for establishment in cultivation.

From May 1942 to October 1944, John T. Baldwin, Jr., conducted a cytogeographic survey of the genus and related genera, mainly in Brazil. With two exceptions, he reported (*4*, *5*), on the basis of hundreds of counts, that all *Hevea* species, varieties, and forms have 36 chromosomes in the reduced phase. These are associated as 18 bivalents at meiotic metaphase. One exception was an individual of *H. pauciflora* (Spruce ex Benth.) Muell. Arg. with 18, and the other was a weak specimen of *H. guianensis* var. *marginata* Ducke with 54 chromosomes, both on the Belterra plantation. Baldwin made many collections, which are now growing at the Instituto Agronomico do Norte at Belem. Notable is a series of *H. pauciflora* clones of good vigor and apparent resistance to the important diseases and insect pests. The best of these clones have been used in experimental crown-budding of Eastern clones on the Utinga plantation of the Instituto Agronomico do Norte. Seibert (*84*) has further emphasized the potential value of *H. pauciflora* as a source of disease resistance in the breeding program.

From July 1943 to January 1947, R. J. Seibert was assigned to taxonomic study and selection work in Peru. Seibert made about 350 jungle and nursery selections, the latter from large juvenile seedling populations, and distributed budwood of many of the numbers to other cooperating countries where the trees are now under test. He published a monograph (*84*) on his studies, including a distributional map of the 6 species and varieties in Peru. He gave much evidence suggesting past intergrading of species and describes many present "putative hybrids," found especially where species distributions overlap and the jungle has been disturbed by shifting agriculture.

Through arduous months following jungle rubber tappers, Seibert (*84*, *85*, *86*) confirmed fragmentary earlier figures and impressions about the superior yield of the upland type of *H. brasiliensis* in the Madre de Dios district of Peru. The same strain of the tree is presumably also the dominant one in the adjacent Acre Territory of Brazil and in the Pando and Beni Provinces of Bolivia and the source of the long-recognized superior-quality jungle rubber from this general region.

Because of these exceptional attributes and the additional high level of resistance to South American leaf blight of most jungle selections from that region, special efforts have been made to study the upland strain of *H. brasiliensis* under more uniform conditions in cultivation. Small seedling populations have been planted at the Los Diamantes substation in Costa Rica, and a large planting has been financed and directed by the Firestone Plantations Co. in Guatemala. The latter contains some 40,000 Madre de Dios seedlings from jungle seed collections, kindly furnished the United States Department of Agriculture in 1948 by the Ministry of Agriculture of Peru for the experiment. The 200-acre planting is arranged not only to obtain an accurate population appraisal of this unique strain, but to obtain cross-pollination of elite trees with the best Eastern breeding clones as well as data on several secondary objectives.

From October 1943 to 1954, Richard Evans Schultes has undertaken a comprehensive taxonomic, floristic, and ecological investigation of the genus *Hevea* throughout its native range as a basis for a monograph on the subject, the first since that by Spruce a century ago. During 1944–45, Schultes worked in Colombia, especially in the Trapezoid area bordering the main Amazon. Here he made careful studies on the famous red- and black-bark trees, a character found to be quite independent of yield or, in fact, of more significant taxonomic characters.

When Baldwin concluded his cytogeographic survey, Schultes transferred his activities to Brazil, with headquarters at the Instituto Agronomico do Norte. Here he had the benefit of the vast taxonomic knowledge of Adolfo Ducke and cooperation with the taxonomists J. Murca Pires and R. de L. Froes. He first worked intensively along the Rio Negro to and beyond the Casiquiare connection with the Orinoco River. The Rio Negro area has long been known for its richness in *Hevea* species as well as the endemic region of its nearest relatives, the genera *Cumuria* (*6*) and *Micrandra* (*79*). He made exploratory trips to the other principal *Hevea* regions, including the Marmellos River, a tributary of the Madeira, to study the little-known *H. camporum* Ducke. Unfortunately, the remote headwaters of the river were too low for his aluminum canoe, illness struck, and the trip ended in near disaster. Except for this, Schultes' 5 years in Brazil, repeating and extending Spruce's travels of a century earlier, enabled field study of the principal regional variants of *H. brasiliensis* and the other species.

With expansion in 1951 of collection of wild rubber in Colombia and establishment of plane service to remote areas, Schultes returned to that country for a further 2-year period to round off his studies of the several poorly known species, varieties, and forms. Many living collections have been sent to nursery centers for further study and selection work. Throughout his jungle travels and brief home leave interruptions, Schultes has already published a series of taxonomic and other articles on his work (*3, 69–82*) that will be expanded to the projected monograph.

Pollination

Since the beginning of *Hevea* breeding work in the Far East and more recently in the Western Hemisphere, an average of only 3 to 10 percent of artificial cross-pollinations has resulted in fruit set. Thousands of tedious and expensive hand-pollinations have been required to obtain even minimum seedling progenies, which then were inadequate for reliable data on inheritance of resistance to disease and other important factors not linked, apparently, with plant vigor or yield.

Because of this low success, Far Eastern workers sometimes first made exploratory crosses to get some idea of the combining ability of their parental selections, then after 6 to 10 years, when yield and other qualities of the progenies could be at least partially appraised, they would either make many hand-pollinations of the best combinations, or establish the parents in isolated duoclonal or polyclonal seed gardens to obtain abundant seed from natural pollination. This required another 5 to 7 years, but, by having demonstrated the parental quality, the seed often could be recommended for direct commercial "clonal seed" planting, as well as a source of individual seedling selections superior to the original parents that could be multiplied as budgrafted clones. In prewar Java, certain enterprising Chinese planters took advantage of this long time-lag by expanding hand-pollinations of some combinations to a commercial scale. With cheap labor and unusual skill, they often secured as high as 40-percent success with the best combinations and found a ready market at 25 guilder cents a seed.

Although many studies of *Hevea* pollination had been made by Eastern workers, the actual method of pollination in nature remained a mystery. All evidence in both hemispheres indicated clearly that insects were responsible (*57*), but no particular insect had been found consistently associated with, even less entering, the tiny female flowers.

For detailed investigation of this problem of low fertility in *Hevea*, considered basic to possible improvement in the breeding program, advantage has been taken since 1950 of the interest of H. E. Warmke, geneticist at the Federal Experiment Station in Puerto Rico, at Mayaguez. This station had cooperated in 1944 by establishing a breeding garden of Eastern and blight-resistant clones for natural cross-pollination. In Puerto Rico, Warmke (*97*) found the usual variety of small insects visiting the odorous *Hevea* flowers, but, as reported by previous workers, none was seen to enter. Then, with the aid of a dissecting microscope, he examined the stigmas of hundreds of female flowers and discovered small brown insect hairs or bristles on the sticky stigmatic surfaces. By a unique type of sleuthing, these bristles were finally identified as belonging to three genera of heleid midges (*Dasyhelea*, *Atrichopogon*, and *Forcipomyia*), which not only lost the bristles but sometimes themselves became stuck to the sticky stigmas. Another small insect, thrips (genus *Frankliniella*), was also implicated as definitely responsible for the relatively few pollinations where pollen grains were found on stigmas in the complete absence of any midge bristles.

The significance of these discoveries made it essential to study the pollination method in Brazil where *Hevea* is indigenous. This Warmke has done. He reported (*98*) that there, also, midges are responsible for most natural pollinations. Four genera of the family Heleidae—*Atrichopogon*, *Stilobezzia*, *Dasyhelea*, and *Culicoides*—were identified, of which the *Atrichopogon* species, in particular, were responsible for most natural pollinations. Thrips, during the time of this study, were few in number and probably of little or no importance.

The midges (approximately 1 mm. in length) are barely visible to the naked eye and are yellowish to dark brown. Their zigzag flight, similarity in color to the flower petals, and appearance only around sunrise and sunset on rainless days probably account for their having been overlooked by previous workers as pollinating agents of *Hevea*. Through further research, the life histories and breeding habits of the midges should become known and, it is hoped, enable their use for controlled pollination, as well as to insure greater and more uniform natural fruit set in open-pollinated seed gardens.

Breeding Gardens

Location

In the cooperative breeding program described earlier (p. 12), arrangements provide for conducting each particular line of crossing at those stations, or in that region or country, where the most effective results may be achieved. Thus, gardens for intercrossing resistant clones to obtain the F_2 or other generations have been located mostly at the cooperative regional station in Costa Rica, where South American leaf blight is always severe and prevents crossing with susceptible material.

All breeding involving the use of the leaf-blight-susceptible but high-yielding Eastern clones can be done best in blight-free areas, such as at Coconut Grove, Fla., on the Island of Hispaniola, in the south of Brazil, and in certain west coast districts of Mexico and Central America. Although leaf blight is present and may seriously damage unsprayed nurseries in the latter regions, it does not injure older flowering trees. At least this has been the long-period experience on the Pacific coast of Guatemala, and there are similar climatic areas both to the north and south, even extending to Panama and Ecuador.

Breeding work outside of Brazil, involving hand-pollinations with Eastern clones, was conducted at Coconut Grove, Fla., and at the cooperative regional stations at Entre Rios, Guatemala, and Marfranc, Haiti, respectively. Open-pollination gardens were also located at Divisa, Panama; Summit Gardens, Canal Zone; and Mayaguez, Puerto Rico. Similar gardens have been established in the State of Bahia, Brazil, and at substations on the coastal area and at Campinas in the State of São Paulo, Brazil. Limited hand-pollinations, involving the older Eastern breeding clones, have also been continued on the Belterra plantation in the Amazon region, where on the exposed Dorados Point these clones are not too seriously damaged.

There is at least a threefold purpose in such widely scattered breeding or clonal seed-producing gardens:

(1) To permit use of clones best adapted to each region, with greater chance of adaptable offspring. Thus, any country with conditions similar to those at one or other breeding station will be particularly interested in resistant selections bred at that station. It would also have under test advanced selections from all other stations.

(2) To insure a wider range of crosses each year, regardless of seasonal and weather influences that may prevent simultaneous flowering of certain clones one year or another in many gardens. The latitudinal effect is also great. Certain Eastern clones that complete their annual flowering in only a few weeks at Belterra (near the Equator) often flower over a period of 4 to 6 months at Marfranc and Coconut Grove, near latitude 18° and 26° N., respectively.

(3) To obtain wider apportionment of expense. New gardens must be established nearly every year to take advantage of new knowledge from the testing program or to introduce promising new material. The 4 to 6 years' timelag between planting and fruiting necessitates the inclusion of only partially tested clones in order to avoid still more loss of time. Thus, most of the resistant clones put into breeding gardens in 1942 to 1945 at many of the above locations could no longer be recommended in 1951 when they reached the flowering age. However, accumulated yield and other data emphasized the value of the remaining clones in these gardens, and the gain of 5 to 6 years by having them at flowering stage in 1951 more than compensated the expense on the discarded portions. An initial density of about 200 trees per acre is required, since more than half of the stand will consist of a half dozen or more improved but not fully tested parents. Later, drastic thinning out of discarded clones will leave an adequate though irregular stand of tested parents for seed production in such polycross gardens.

Resistance Testing and Selection Work

For both methodology of testing and classification of hevea seedlings of different degrees of susceptibility or resistance to South American leaf blight, reference is made to the detailed publications of Langford (*37*, *38*, *42*), who has directed this phase of the breeding program for many years. All seedlings with a numerical blight rating of 6+++, or higher, would be severely damaged in areas such as the northern coast of Costa Rica, where the disease spreads readily throughout the year. Ratings of 5, or less, offer greater commercial safety in all areas.

Reliable resistance ratings on seedling progenies or new clones can be secured within 6 months to 1 year only in certain localities, more particularly at the regional station in Costa Rica. Here, weather conditions can be counted upon every year to favor epidemic spread of leaf blight and usually also phytophthora leaf fall from a minimum adjacent source of inoculum on susceptible plants. Langford has demonstrated that natural infection and spread under favorable conditions give a much more severe test of resistance than any artificial inoculation yet devised.

Such favorable natural conditions for disease spread may also occur periodically in all the other infested countries, but they cannot be relied upon to occur every year. Thus, the testing nurseries must be retained and costs are increased. This is true especially in Brazil and Guatemala. Here, after the first year, the apparently resistant selections are cloned and budwood sent to Costa Rica for a further test. Later on, all advanced selections, whose preliminary yielding capacity is known, are tested in several localities of the Amazon countries to make certain of their exposure to different regional populations of the leaf blight fungus. By this procedure during the past 10 years, several clones already in limited commercial use for topbudding because of their resistance in Central America have had to be discarded.

Seed produced at breeding gardens in blight-free areas were regularly air expressed to Costa Rica for germination and resistance tests. Open-pollinated seed were collected only from the susceptible Eastern clones in such gardens. Thus, any seedling that comes from such lots of seed and that displays resistance in Costa Rica must necessarily have come from a cross with a resistant parent. All selfed seedlings as well as those from crosses with some other susceptible Eastern clone will be susceptible and can be quickly eliminated.

Limitations of the program prevent, unfortunately, any use of seed from the reciprocal cross; i. e., seed produced by the resistant clones in open-pollination, susceptible × resistant, gardens. Resistant seedlings could be identified, but there would be no certain way, short of yield tests, to differentiate susceptible × resistant seedling from the resistant × resistant, most of which in some crosses would be very low yielding and greatly increase the cost of the program.

Hevea breeders in Southeast Asia and Africa, fearful of the consequences of South American leaf blight spreading to those regions, have expressed interest in receiving seed from the reciprocal cross and in other phases of the Western Hemisphere breeding program. In August 1952, the first small lot of seed collected from resistant parents in mixed seed gardens was dispatched from Summit, Canal Zone, to Malaya after careful disinfection and later quarantine detention en route at Kew Gardens, London. In a few years, when preliminary yields are known, budwood of the selections can be returned to the West for blight-resistance ratings. The discovery of any resistant and otherwise valuable numbers will more than repay both cooperating agencies for costs involved. Participation by other Eastern countries and extension of the cooperation to other phases of the breeding program should result in great future benefit to the rubber industries of both hemispheres.

FIELD INVESTIGATIONS

As a new long-period crop for Latin America, hevea culture has presented many production problems. The question of temporary or permanent intercropping of rubber, so important for a small-farm industry, has also received much attention. Fortunately, advantage could be taken of the results of a half century of research in the several countries of Southeast Asia. Just as those countries have modified their field practices as a result of research and increasing costs of labor, still greater modification and adaptation of methods have been required in the Western Tropics.

Climate and soil show considerable similarity in the following Eastern and Western countries, respectively: East Java and the west

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coast of Guatemala; West Java, the East Coast of Sumatra, and the eastern coasts of Central America and of the State of Bahia, Brazil. The coastal soils of Malaya are similar to the porous plateau soils of the lower Amazon, but have a uniform rainfall distribution contrasted with a prolonged dry season in the lower Amazon. The lateritic soils under comparable rainfall give about the same growth response in both hemispheres. The same is true of the deep alluvial soils on which rubber is grown in Indochina, and those soils of similar derivation in the West.

These rough comparisons were helpful in the beginning of the cooperative program in the selection of Eastern clones for commercial planting in several of the countries. However, results of preliminary yield tests are already modifying the recommendations, as might be expected.

Rubber Yields

Clones for crown budding and for yields have been planted in each cooperating country in connection with the plant multiplication and distribution center. (See fig. 1.) Replicated experiments were first started with those Eastern clones that might prove suitable in a particular country. The tests also included comparison of different leaf-blight-resistant clones for topbudding, both for compatibility with specific panel (Eastern) clones and their suitability with respect to similarity of vigor and crown conformity for a polyclonal canopy. A mixture of 4 to 6 different crowns has seemed essential to counteract specialization and eventual damage from the South American leaf blight and other fungi. More recently (1948–49), certain FX *benthamiana* hybrids have been included in the crownbudding tests because of their resistance both to leaf blight and to phytophthora leaf fall, as determined at the regional research station in Costa Rica and following demonstration in 1945 of their outstanding value in a 40-acre commercial area on the Belterra plantation in Brazil. In a recent communication C. H. T. Townsend, Jr., United States technician at Belterra, states, "The crown clones with a *Hevea benthamiana* parent show a panel growth rate of 15 to 20 percent over the pure *H. brasiliensis* crown selections."

As jungle tree and nursery selections have become available for testing, either as crown clones or for yield, they have been first established in 5- to 8-tree plots in a "clone museum" at the experiment stations. Any that show promise, based on preliminary yield, are then established in replicated plot experiments.

All selections from the breeding progenies, as described in an earlier section, are likewise first established in a clone museum, usually at the resistance testing station in Costa Rica. Later, upon preliminary yield appraisal, budwood of selected numbers may be distributed to other cooperating stations and replicated tests of the best numbers are planted locally.

At Belterra, more than 2,000 individual selections from the 1937 to 1943 breeding seasons have been test tapped in these initial museum plots. The results have warranted the replanting of some 20 of these primary selections in replicated plot experiments, with suitable controls, to determine more accurately their potential commercial value under local conditions. At the same time, through the cooperation of

Brazil, most of these advanced FX selections that have approached or equaled the Eastern clones in apparent yield in the museum plots have been distributed and are being tested similarly in the other cooperating countries.

Many of the yield tests of selections and other field experiments have been incorporated in commercial rubber plantings of reliable private companies and growers who were receiving technical assistance through agencies of the cooperating tropical American governments.

Limitations on available land, the high capital cost, and the long duration of such experiments have dictated that wherever possible they be incorporated into commercial plantings. The interested growers who have assumed these costs are basically interested in the new clones or the new methods and are willing to accept the chance of some reduction in yield on these particular plots. The plots are designed to serve their scientific purpose while minimizing the chance of material loss, since a skeleton of proved clones is provided so that eventual thinning will leave the area with a commercial yield even though the test clones prove worthless.

Planting Systems

Limited research in the Far East has favored the avenue, or semihedge, type of tree spacing, which gives fewer rows to be maintained, less walking by the tapper in proceeding from tree to tree along the row, and less wind damage than the old square and equilateral-triangular systems. The growth of trees, crowded within the row but free to spread laterally between the rows, is not retarded as soon as with the older systems with competition on four sides. Therefore, a greater initial density of trees and higher yield per unit of area during the first years should be achieved.

An initial spacing of 3 by 6 meters (9.8 by 19.7 feet), giving 555 trees per hectare or 225 per acre, has been adopted in many Western Hemisphere plantings. There is inadequate knowledge of the adaptability of many of the Eastern clones to local conditions. Thick planting of a polyclonal mixture of these clones will allow severe thinning of those that prove unsuitable, or trees that are retarded because of unequal growth caused by topbudding or for any other reason. Commercial trial of several other spacings is under way in demonstration plantations. The regional station in Costa Rica recommended in 1950 a 2- by 10-meter (6.6- by 32.8-foot) spacing for all small-farm plantings. This accommodates 500 trees per hectare, or 203 per acre.

At the regional station in Costa Rica, a replicated experiment comparing 6 spacings was planted in 1945. These, given in meters, are 3 by 6, 2.4 by 7.5, 2 by 9, 1.6 by 10.7, 4.2 by 4.2, and 4.5 by 4.5 by 4.5 (triangle), each requiring 555 trees per hectare, or 225 per acre. The results of this experiment and similar tests at other locations emphasize the advantage, especially for small growers, of having wide rows that permit, during the first 3 to 4 years, intercultivation of food crops or other catch crops until shade from the rubber no longer permits. The economic advantages of such temporary intercropping, even for larger plantations, have been shown by Morales, Bangham, and Barrus (*56*). Therefore, as a matter of expediency, Imle and Manis have suggested a tree spacing of about 2 by 9 or 2 by 10 meters for all small-farm plantings. The 2 by 10 meters (6.6 by 32.8 feet) has permitted intercropping for 6 years, rather than 4 years as with the 3- by 6-meter spacing.

Intercrops and Ground Covers

Small-farm rubber plantings are usually interplanted with food crops during the first 4 to 6 years, or until shade from the rubber prevents further normal growth. The following food and other crops have been noted in such locations in the various countries and many of them have been tested for suitability in demonstrational rubber plantings at the principal regional station in Costa Rica: Cabbage, cassava (yuca), citronella and lemon grasses, derris, peanuts, pineapples, beans, corn, bananas, sugarcane, sweetpotatoes, and taro. Figure 6 shows typical intercropping.

Necessary cultivation of these crops is generally beneficial to the rubber on land not subject to serious erosion. However, cassava (yuca) may offer serious competition if planted too close to the rubber-

FIGURE 6.—Temporary intercropping of rubber with food crops at the Costa Rica regional station. Taro (tiquisque), at left, and cassava (yuca), at right, of a row of 25-month-old 3-component hevea trees.

trees and the trash from harvested sugarcane presents a serious fire hazard, as experienced in small-farm rubber plantings in Mexico.

Following the above intercropping, a suitable and permanent ground cover is desirable to reduce weeding costs, prevent erosion, and enrich the soil. However, the small farmer will not be interested in this unless it has accessory value for his family or for his livestock. Tropical kudzu (*Pueraria phaseoloides* (Roxb.) Benth.) and certain other legumes partially meet this requirement. Considering the general shortage of protein for livestock throughout Latin America and the successful pasture of pueraria on the Fordlandia plantation in Brazil, cooperating agencies should encourage its use. Pueraria fails to withstand deep shade, as well as intense grazing, but it may be browsed in the afternoon hours when the latex has been collected and there is no damage in connection with the rubber tapping.

Since pueraria is initially difficult to establish in many localities and later gradually dies out in mature, completely shaded rubber plantings, the station in Costa Rica has conducted research to find more generally suitable ground covers. During the period of March 1945 to November 1947, M. F. Barrus assembled more than 100 species of local and introduced legumes and tested more than a third of these under various situations. A few are continuing under observation in rubber plantings, and in another few years a general summary and recommendations on the subject should be possible.

Permanent Mixed Cropping

Far Eastern research on permanent mixed cropping has been reviewed in earlier publications by Rands (*63*, *64*, *65*, *68*). Much interest has recently developed in Latin America in the use of rubber as shade for lowland coffee and even for Arabica coffee at median altitudes of 1,500 to 2,200 feet. Many plantings are being made in Guatemala and Haiti, with plans under development by the governments of several other countries.

Demonstrational plantings of both rubber-coffee and rubber-cacao mixtures, initiated at the Turrialba station by Rands and Imle, have attracted much interest in recent years. However, more experience, preferably from larger commercial trials, will be required before recommending the combination of rubber with cacao. In wet areas, such as northern Costa Rica, *Phytophthora palmivora* Butl. has severely affected both crops in separate plantings, causing pod rot of cacao and leaf fall, fruit rot, twig dieback, and tapping panel canker of all susceptible hevea clones. There is little reason to expect that phytophthora will be worse on either crop when grown in a properly planted mixture than when either one is grown separately, but only limited areas should be planted to this combination until more evidence is available from pioneer tests at the Costa Rica stations. A young experimental planting of hevea with cacao at the Costa Rica station is shown in figure 7. Here, the 3-component hevea trees are provided with *Hevea benthamiana* hybrid crowns.

FIGURE 7.—Avenue planting of 25-month-old 3-component rubbertrees spaced 6 by 10 feet with 90 feet between avenues, which are interplanted with cacao at a spacing of 10 by 10 feet with 15-foot clearance from the rubber. The cacao is provided with temporary shade of *Leucaena glauca* Benth. until the rubbertrees are large enough to shade the cacao. A nonclimbing leguminous ground cover of *Indigofera endecaphylla* Jacq. reduces weeding of the rubbertrees.

HISTORY AND STATUS OF THE RUBBER PROGRAM IN COOPERATING COUNTRIES

What the Project Accomplished

In the above subject-matter review, reference is frequently made to activities and progress in the cooperating countries. The 15 Latin American Republics, with soil and climatic conditions suitable for the culture of hevea, participated in the joint rubber survey of 1940–41. Under the stress of the rubber shortage during World War II, most of these countries supported the inauguration of a cooperative rubber planting program. In the postwar adjustment, financial support and official participation by the governments of 6 of the countries (Ecuador, El Salvador, Honduras, Nicaragua, Panama, and Venezuela) were greatly reduced, placed on a maintenance basis, or discontinued. However, in most of these countries, official interest in the objectives of the program continues, and this Department has been encouraged by several of the countries to cooperate directly with, and provide technical guidance to, private companies and individuals who planted some 1,400 acres of rubber in those 6 countries during the earlier years.

The remaining 9 countries (Bolivia, Brazil, Colombia, Costa Rica, Dominican Republic, Guatemala, Haiti, Mexico, and Peru) continued active participation through official financial support, assignment of local technicians, and miscellaneous contributions toward advancement of the cooperative program. The actively cooperating countries were reduced to 8 in June 1953 by the withdrawal of the Dominican Republic from the cooperative project. Such unwavering interest through the years attests their conviction in the fundamental soundness of the program and of its ultimate benefits to their national economy.

Table 1 presents statistical estimates by country for 1953 on several phases of the program that indicate comparative emphasis and progress in the 9 actively cooperating countries. Some of the reasons for the extreme differences are indicated elsewhere in this circular (p. 70); these are need for self-sufficiency in their own manufacturing requirements, or need to export on the world market. In those countries (chiefly the smaller ones) relying mainly on export, possible future competition from synthetic rubber has been a real deterrent in expansion of acreage. Even in these countries, for example, Guatemala, where rubber has been about the only source of year-around cash income for small, lowland farmers, the local sales and exports have been a powerful stimulus for extension of plantings.

Estimated total investment by cooperating governments and private interests in the rubber program exceeded by more than 4 times expenditures by the United States government for cooperative research and technical guidance during the year 1953. Similar annual ratios of expenditure, ranging from 2:1 to 4:1, have characterized the program since its inauguration in 1940.

During fiscal years 1953 and 1954, some 30 United States technicians were assigned by the United States Department of Agriculture to this cooperative program, centered mainly in 9 Latin American countries, Puerto Rico, and Coconut Grove, Fla. The latter 2 United States experiment stations served for special research projects and as a plant material quarantine center, respectively. Four of these technicians—a geneticist, a pathologist, and 2 plantation advisers—have each served several countries on a regional basis. Few technicians having long experience with rubber have been available. Chief advisory responsibility for the considerable investments of cooperating governments and companies in the rubber program, therefore, has necessarily been carried by the experienced regional technicians and the technical administrative staff of the United States Deparment of Agriculture.

No precise estimate of the number of cooperating technicians in the various countries has been attempted. Some are part-time workers on rubber in connection with other crops and many are seasonal only during the annual period for planting new areas. The total, excluding trainees, would probably exceed 100.

TABLE 1.—*Estimated cost and rubber acreage established in cooperating countries, 1953*

Country	Estimated expenditures for research, development, and production by—				Clonal trees—		
	U. S. Department of Agriculture [1, 2]	Latin American countries [3]			In production	Planted in 1953	Total
	Direct	Direct	Commercial [4]	Total			
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Number*	*Acres*	*Acres*
Bolivia	5, 584	10, 000	10, 000	20, 000	---	125	125
Brazil	54, 535	200, 000	1, 800, 000	2, 000, 000	800, 000	8, 500	37, 125
Colombia	19, 658	12, 000	60, 000	72, 000	1, 500	100	775
Costa Rica	67, 025	12, 000	175, 090	187, 000	190, 000	50	2, 960
Dominican Republic	4, 887	10, 000	---	10, 000	4, 000	30	270
Guatemala	14, 633	30, 000	50, 000	80, 000	37, 000	300	2, 000
Haiti	18, 950	10, 000	30, 000	40, 000	104, 000	50	1, 400
Mexico	27, 743	50, 000	75, 000	125, 000	72, 300	45	3, 070
Peru	9, 829	11, 000	100, 000	111, 000	1, 000	100	745
Regional [5]	101, 271	---	---	---	---	---	---
Total	324, 085	345, 000	2, 300, 000	2, 645, 000	1, 209, 800	9, 300	48, 500

[1] In addition to funds assigned to the U. S. Department of Agriculture for obligation on the field program, The Institute of Inter-American Affairs allotted an additional sum of $225,000 for expenditure by directors of technical cooperation in the individual countries. This, plus administrative costs, makes a grand total of $589,085 estimated total United States expenditure.

[2] Fiscal year July 1, 1951, to June 30, 1952.

[3] Calendar year 1953.

[4] Includes rubber plantings financed through government loan and by private companies.

[5] "Regional" includes mainly salaries and expenses of four regional advisers, maintenance of plant quarantine facilities and breeding gardens at Coconut Grove, Fla., special cooperative research on breeding in Puerto Rico, and the overall technical direction of the program from the U. S. Department of Agriculture Plant Industry Station, Beltsville, Md.

In the following sections of this report, brief summaries are given on the history and present status of the program in individual countries. Here, again, reliance is placed on estimates only by United States or local technicians, since accurate data were in many cases unavailable.

Bolivia

Background

Since 1900 Bolivia has usually ranked second only to Brazil as an exporter of wild rubber. This is produced in the extreme northwestern districts of the Republic, principally in the Departments of Beni and Pando. The general region is geographically similar to the adjacent Acre Territory of Brazil and Madre de Dios of Peru and contains some of the best developed and highest yielding native hevea rubbertrees of the Amazon Valley. General features of this remote area are described in the Department of Commerce survey report of 1925 (*83*).

On July 15, 1942, in order to stimulate increased production during the rubber shortage of World War II, the United States signed a 5-year rubber purchase contract with the Bolivian Government and established a development fund of $2,125,000 to make the producing areas more healthful and increase food production. These measures resulted in a considerable influx of laborers, and by 1945 net rubber exports were practically quadrupled compared with those of the late 1930's. With the expiration of this contract on December 31, 1946, the Bolivian Government was forced to subsidize continued production, at least on a reduced scale, to maintain the tappers and dispose of the product whose cost exceeded the world price.

Although actual marketing of the rubber has always been in the hands of a few large companies and landowners, the above course of events intensified the desire of both producers and government to encourage rubber plantation development and thus decrease the cost of production. Accordingly, technical assistance on rubber planting was requested under the general memorandum of agreement of April 1943, between the Ministry of Agriculture of Bolivia and the United States Department of Agriculture. It was not, however, possible for budgetary and other reasons to assign a technician until August 1951, when Paul Tobler, Jr., was engaged to initiate cooperative work.

Establishment of Project

At the request of, and through arrangements made by, Bolivian Government officials, a cooperative project was set up with three interested private companies. The headquarters were in the town of Riberalta, located at the confluence of the Madre de Dios and Beni Rivers. A missionary group, known as the Maryknoll Fathers, also had its establishment and farm near this place and desired to help small farmers along these rivers in the planting of rubber.

The Bolivian Servicio Agricola Inter-Americana (SAI) Agricultural Experiment Station at Santa Cruz became the local administrative agency for the rubber project. Through this agency, 12 hectares of land for initial rubber nurseries were acquired and a residence and other facilities for the rubber technician constructed with Bolivian funds.

High-yielding Eastern (panel) clones and resistant clones for top-budding were introduced from the regional station in Costa Rica and from adjacent Peru. Resistant seed for rootstocks was introduced from Brazil through the courtesy of the Instituto Agronomico do Norte at Belem. This primary plant material multiplication and distribution center, comprising in 1953 about 3 hectares, at Riberalta provides initial supplies of known rubber clones to the cooperators for further multiplication in their own nurseries for field planting.

During 1952, rootstock seedling nurseries of 130,000 trees were established by the cooperating companies on their various farms above Riberalta along the Beni and Madre de Dios Rivers. Although remote, the soils along the Beni (in the region of San Pedro) are among the most fertile in the whole Amazon Valley.

Table 2 gives reported plans for 1954 of private cooperators for initial rubber plantings in the Beni area. According to Paul Tobler, United States rubber technician, several clone comparison and other experiments were to be included in the larger commercial fields.

Preparations were made for scheduled planting of 250 hectares per year for the next 5 years. While these initial plantings are limited to the Beni area, there is believed to be good possibilities in the San Ignacio-Delasco area northeast of Santa Cruz and the Todos Santos area northeast of Cochabamba.

In consequence of the recent land reform law, it has been predicted that wild rubber gatherers will leave the "patron" in ever-increasing numbers and take up land for individual farming. Consequently, the picture in the Beni area may gradually change from that of wild rubber gathering, with all its miseries, to that of a land, however isolated, of small farmers with cultivated rubber production as the chief source of cash income. This will not materialize without some assistance. Bolivian technicians are being trained to guide the rubber development, which, if consistently supported by the Bolivian Government, should produce good quality rubber in competition with the world market both for domestic use and export to the adjacent large rubber-consuming nations of Brazil, Argentina, and Chile.

TABLE 2.—*Initial experimental and demonstrational rubber plantings in the Beni area of Bolivia, 1953 and 1954*

Cooperator	Location	Nursery trees in 1953	Proposed planting for January to March 1954
		Number	*Hectares*
Seiler Co	Conquista	54, 000	64+
Do	Fortaleza	15, 000	16
Sonnenschein	San Pedro	57, 000	65
Suarez Hnos	Sena	15, 000	(?)
Maryknoll Fathers	Mission Cavinas	0	16
Oliver Bros	San Roque	0	10
Total proposed			171+

Brazil

Historical Summary

Brazil and the adjoining countries of the Amazon basin represent not only the native home of the hevea rubbertree, but it was in Brazil, particularly, where hevea was also first exploited more than a century ago. Up until about 1910, when the Far Eastern plantation product became available in large volume, the production of native (wild) rubber dominated the world rubber markets. Wild rubber in recent decades has been reduced to minor export significance, but Brazil has continued to encourage its production for home consumption through valorization or other subsidy arrangements. Despite all efforts, local use in recent years has outrun production and imports of plantation rubber from the Far East, as well as the synthetic product from the United States, have been necessary. Consternation over this unprecedented situation, following stringent rationing of the product during World War II, has prompted a program of needed research and plantation development to achieve national self-sufficiency in rubber.

The planting of rubbertrees is no new development in Brazil. Records, compiled in 1923–24 by the joint rubber survey of the United States Departments of Commerce and of Agriculture and cooperating Brazilian scientists (*43*, *83*, *99*), show that many thousands of rubbertrees were planted in Brazil before there was developed any sizable industry in the Far East. These trees were in isolated areas scattered over an immense region and had no adequate attention. Confronted with the problems already enumerated in this circular, their failure to develop as plantations do today is understandable. Even during World War II, hundreds of jungle tappers planted rubber seed in their food-crop clearings along the "high-bank" tributaries of the Amazon as their predecessors had done for decades. In these regions, a considerable part of the "wild" rubber collected today is said to come from the surviving trees planted since 1875.

In the State of Bahia, there were also several periods of rubber planting, particularly around 1910–13, again in the early 1920's, and, more recently, during World War II. The trees were planted mostly as shade for cacao, and several plantation-size areas were developed, though never extensively exploited until the wartime rubber shortage. It was then that South American leaf blight suddenly became epidemic and, through successive defoliations of the trees, reduced latex yield to a fraction of anticipated production. The disease had apparently been introduced earlier with plant-material shipments from the Amazon region.

In all the early hevea plantings throughout Brazil, including the pioneer Fordlandia plantation developed in the late 1920's, only unselected low-yielding seedlings were planted. Conclusive proof, obtained in the second Ford attempt on Belterra plantation, that high-yielding Eastern clones, provided with resistant crowns, could be successfully grown, gave the necessary impetus for the present firm national policy for encouragement of rubber planting. After all the disheartening earlier experience, including the failure of Fordlandia and near disaster at Belterra, it required utmost courage and perseverance of scientific leaders, such as Felisberto C. de Camargo and Barcellos Fagundas, to restore public confidence and obtain national support for the extensive program of recent years.

Cooperative Research and Development Program

In October 1940, a cooperative agreement was signed by the Ministry of Agriculture of Brazil and the United States Department of Agriculture to conduct joint research and guide the sound development of a rubber plantation industry.

First, a survey by 4 Brazilian and 4 United States technicians was made of many of the existing rubber plantings to gain an up-to-date understanding of the problems to be solved. It was decided to limit the program to the Amazon Valley and to establish research headquarters at the newly constructed Instituto Agronomico do Norte at Belem. Permission was granted the official agencies by the Ford Motor Co. to utilize freely its collection of Far Eastern clones and resistant jungle selections in the research program, as well as to supplement its own breeding program then in its third year of operation.

Resistance-testing and plant-multiplication nurseries were established at the Instituto Agronomico do Norte, and field plots with the more promising material were planted on the Instituto farm. Large lots of jungle seed were collected from various districts of the Amazon, and exchanges for clones and Philippine clonal seed were arranged with the regional station in Costa Rica and The Goodyear Rubber Plantations Co. in Panama and Costa Rica. The striking differences between these seedling populations in reaction to leaf blight in these two widely separated parts of tropical America, as reported by Carl D. Butler, temporarily assigned to Belem, and M. H. Langford, in Costa Rica, already have been shown in figure 5. Similar evidence from Peru on the behavior of local and introduced material further emphasized the necessity of a coordinated breeding and disease-testing program for production of superior clones that would maintain their resistance in all cooperating countries.

The contributions of Brazil toward advancement of the rubber planting projects in a dozen other countries have not always been appreciated. It is a fact that every disease-resistant clone now recommended for commercial use originated in Brazil and that the newer hybrid clones showing greatest promise of combining resistance with superior yield were produced there in the cross-pollination program.

From 1942 to 1944, L. A. Beery, Jr., of the United States Department of Agriculture, cooperated with the Instituto Agronomico do Norte in initiating large-scale programs of hand-pollinations on the Belterra plantation. Thousands of hybrids between resistant, but low-yielding, selections and susceptible high-yielding Far Eastern clones were produced and shipped to the Instituto Agronomico do Norte at Belem for resistance tests. Selections were then put into field plots for yield tests, and many were distributed to other cooperating countries.

Through cooperation with the Brazilian geneticist, George O'Neal Addison, a large hevea breeding program has been conducted each year since 1942. The detailed work has been directed by C. H. T.

Townsend, Jr., and the resistance tests and selection work aided by M. H. Langford.

Since January 1946, when the Brazilian Government purchased the Ford rubber plantations (Fordlandia and Belterra), the Instituto Agronomico do Norte has operated the two plantations as a substation. Large experimental plantings have been made, and huge multiplication nurseries are maintained so that the Instituto Agronomico do Norte is able to supply budwood of the best clones to all persons interested in planting rubber.

Among the investigations of secondary importance, the following may be cited: Several 40-acre blocks of the Belterra plantation were planted by the Ford Motor Co. with seed from Tapajoz jungle trees, and directly adjacent blocks with similar seed collections from the down-river region of Belem. In early trade literature, the lower tree yields and poorer quality of rubber from the lower Amazon and island areas were ascribed to the annual flooding and otherwise less favorable conditions as compared with the yields and quality of the high-land *Hevea brasiliensis* of the Tapajoz and similar areas. The above plantings offered an opportunity for comparing the yields of seedlings from the two sources under the uniform conditions at Belterra. Accordingly, during 1953, Mr. Townsend supervised tapping tests of about 350 trees of each category. Average girth of the Belem trees at 3 feet height was 31.0 inches and for the Tapajoz, 26.1 inches. The average yield of dry rubber per tree per tapping was 2.9 grams and 5.6 grams, respectively. Even though of smaller size, the yield of the Tapajoz trees was nearly double that of the Belem trees, and this supports the theory that the latter constitute a genetically different strain of the species rather than the differences being an exclusive effect of environments.

From 1945 to 1948, H. G. Sorensen, agriculturist of this Department, was stationed at the Instituto Agronomico do Norte to guide development of the experimental-demonstrational plantation "Utinga," near Belem. The soil and climatic conditions of the lower Amazon, typified at Utinga, are widely different from those at Belterra and make this small plantation a most valuable adjunct to the general research program.

By 1951, inauguration of the Point IV program, in conjunction with rapidly increasing demand for rubber for Brazil's expanding economy, combined to provide the incentive for enlarging the cooperative rubber program. Up to this time, interest in planting rubber had been limited, but public indignation over the necessity for importing Far Eastern rubber aroused interest in planting and expanding the program outside the Amazon Valley. Brazil requested the United States Department of Agriculture to furnish additional technicians for both research and development phases.

In December 1952, L. A. Beery, Jr., was reassigned to Belem, Brazil, as chief United States representative on the rubber program, to work with the Ministry of Agriculture in coordinating the cooperative research and development activities of the enormously expanded rubber program. An integrated program, involving all United States Department of Agriculture field technicians, the Instituto Agronomico do Norte, the Instituto Agronomico do Leste, and the other cooperating agencies in Brazil, was achieved.

The research work of the Instituto Agronomico do Norte, including cooperative projects since 1943, has been published as technical bulletins and circulars. The principal ones pertaining to hevea culture are by Camargo (*15*), whose 2-hectare plan for small farmers was adopted by the Credit Bank as one part of its promotion program; by Luis Mendes (*54, 55*) on cytology and pathology of *Hevea*; and, more recently, by Langford (*39*) on *Hevea* diseases in the Amazon Valley. Through cooperation with the United States National Bureau of Standards, a modern rubber assay and quality-testing laboratory was established. Bekkedahl (*8, 9, 10*) has described this facility, which continues of great value for determining the quality of rubber from the numerous interspecific hybrids and selections considered for commercial recommendation.

Future progress in solving existing problems and establishing increasing areas of permanent high-yielding rubber plantings in Brazil seems assured. It has been estimated, however, that more than another decade will be required for rubber production to catch up with the rapidly increasing internal consumption.

Expansion of Amazon Program

In August 1951, A. M. Gorenz, pathologist, was transferred from Mexico to the Instituto Agronomico do Norte to investigate disease problems and, in cooperation with M. H. Langford, to test breeding progenies for resistance. In March 1952, Locke Craig, agriculturist, was assigned to assist the Instituto Agronomico do Norte on development phases. Through the Instituto, he advised other cooperating agencies and private growers. The principal cooperators in the Amazon Valley are the Banco do Credito da Amazonia, the Federal Territory of Amapá, and the state extension services. The bank and Territory are financing and directing rubber planting by numerous colonists and other small growers, while technical assistance only is provided the larger farmers.

A summary of new rubber planting made in 1952 and 1953, under supervision of the credit bank, is presented in table 3.

Table 3 shows a total of 1,104 hectares (2,726 acres) planted, but a large proportion represents only transplanted seedlings, or seed planted "at stake" to be, in future years, basebudded with high-yielding clones and later topbudded with resistant clones. In 1954, an estimated additional 1,000 acres were to be planted. Distances and inadequate transportation have made it difficult for the cooperating government technicians to follow these widespread planting activities closely.

TABLE 3.—*Summary of rubber plantings under supervision of the Banco do Credito da Amazonia, 1952 and 1953* [1]

Area	Nurseries	Trees planted in nurseries	Cooperators	Field plantings	Trees planted in field	Area of field plantings
States	*Number*	*Number*	*Number*	*Number*	*Number*	*Hectares*
Amazonas	1	3, 000	18	17	27, 544	49
Mato Grosso	1	8, 500	1	1	20, 480	37
Para:						
Belem-Bragança	16	63, 100	25	23	84, 910	152
Islands	11	43, 500	15	12	23, 584	42
Tapajoz River	6	37, 000	12	11	35, 572	64
Territories						
Acre	4	10, 500	5	4	8, 520	15
Amapá	10	81, 300	53	47	406, 786	726
Guapore	6	16, 600	11	8	16, 498	29
Total	55	263, 500	140	123	623, 894	1, 104

[1] Estimates supplied by officials of the bank.

State of Bahia

Keith L. Truettner, agriculturist, was assigned to the State of Bahia to cooperate with the local technicians, Osias A. Matos and Anton Bachtold, of the Una substation of the Instituto Agronomico do Leste (IAL) at Cruz das Almas. Nurseries, multiplication gardens, and experimental plantings have been established at Una, fazendas Victoria and Mucambo, and at Urucuca with material received from the Instituto Agronomico do Norte, Haiti, and from Costa Rica. The program has expanded so rapidly that a second field technician of wide experience, T. E. McAuley, was assigned in 1953. During that year, a total of 240 hectares (593 acres) of field plantings of budded material was to be established by the various cooperators. For 1954, an estimated 1,130 hectares (2,790 acres) were scheduled for planting. The program has been limited by shortage of planting material, to be alleviated in 1954 by budwood from the new multiplication nurseries.

State of São Paulo

This State, having the largest rubber manufacturing industry, has since 1951 appropriated funds for both *Hevea* research and plantation encouragement. The project is directed by the Instituto Agronomico at Campinas and, through arrangements with the Federal Ministry of Agriculture, by United States technicians stationed elsewhere in Brazil. These technicians, through periodic visits, gave assistance on both research and planting projects.

Nurseries have been established at Campinas, Ubatuba, Caraguatatuba, Itanhaen, and Santos, the last four in the hot coastal zone. At this time, South American leaf blight has not spread to the State of São Paulo, the most southerly area in South America where hevea culture is being attempted. Permanent freedom is not anticipated, so that topbudding with resistant clones has been advised. In 1952, The Firestone Plantations Co. furnished high-yielding clonal seed from Liberia, and, in 1953, some 25,000 of the resultant seedlings were to be planted on many small farms under supervision of the station at Campinas. The substation at Ubatuba and nurseries at the other locations will furnish budded material for more extensive field planting during 1954 and later.

Colombia

Background

Colombia, even more than Brazil and Peru, is confronted with the necessity of importing a constantly increasing proportion of her crude rubber requirements to meet the needs of her rapidly expanding economy. Also, like those countries, the cessation of United States support for stimulation of wild rubber collection left a postwar economic and political situation that has forced government subsidization of the rubber tappers over Colombia's immense Amazonian districts. From a reported consumption of 175 long tons in 1941, local needs increased to about 5,000 tons in 1952. Of the latter, some 400 tons represented expensive wild rubber. It is generally predicted that consumption will more than double in the next 10 years.

Cooperative Program

Even before World War II, Colombian leaders were concerned about such a probable disparity between production and consumption, and, for strategic and economic reasons, wholeheartedly endorsed the 1940 proposal of the United States Department of Agriculture for cooperative research and encouragement of economic plantation rubber production in the country. Therefore, an agreement, dated December 27, 1940, between the Minister of National Economy and the Chief of the Bureau of Plant Industry, United States Department of Agriculture, authorized a joint survey by experts on the flora, soils, plant diseases, and possibilities of rubber production in the various districts and the designation of those areas deemed most suitable for establishment of plantations.

Following a brief field reconnaissance, an agreement authorizing further cooperative work in starting a rubber planting industry was signed by the above officials on January 28, 1941; and this, together with a supplementary agreement authorizing participation by the official Caja de Credito Agrario, Industrial y Minero, signed June 28, 1943, constituted the continuing basis for the cooperative rubber program in Colombia. Since 1943, the Caja has served as the official operating agency in developing nurseries and initial demonstration plantations.

In June 1946, the United States Department of Agriculture issued processed publications in both English and Spanish (*30*), summarizing the field surveys and the program achievements through 1945. The survey revealed that all essential requirements for the cultivation of rubber were more nearly combined in the Atrato Valley, although conditions appeared favorable in several smaller districts—(1) near Buenaventura on the west coast, (2) near Acandi on the Isthmus of Panama, (3) scattered areas along the lower Magdalena River, and (4) a north coastal zone east of Santa Marta.

In the Atrato Valley between Dabeiba and Turbo and some distance back from the banks of the Rio Atrato and Rio Sucio, immense tracts of well-drained, gently sloping land with deep friable soils were found in a suitable climatic belt. Numerous experts have expressed the opinion that these tracts are among the best in the world for rubber culture.

In 1941, the Government of Colombia decided to complete the highway to the sea (Carretera al Mar) connecting Medellin with Turbo. To do this the stretch of road between Dabeiba and Turbo had to be completed. Plans were made to complete this work in the shortest time possible and operations were started from both ends. Since completion of this part of the road would give access to the relatively undeveloped areas suitable for rubber growing in the Atrato Valley, the cooperating government decided to establish initial plantation centers in this region. An interested banana company near Acandi was aided in 1941 and 1942 in starting one of the first hevea nurseries, but, because of subsequent financial difficulties, it established only a small field planting. A temporary nursery was also planted along the highway leading out from Turbo.

Late in 1942, H. G. Sorensen, agriculturist, was assigned by the United States Department of Agriculture to serve as adviser to the rubber project in Colombia. In cooperation with the Colombian agronomists Francisco Luis Arenas and Juan A. Giraldo, a more detailed examination of the Atrato areas was made. It was decided to establish initial nurseries (1) on the Rio Apartado, where a considerable population was settled and small-farm development combining rubber with other crops could be stimulated; (2) at Rio Grande, 23 miles southeast of Turbo, near a colonization project and in the center of an extensive area of land still owned by the government; and (3) at Villa Arteaga, 68 miles south of Turbo and 48 miles northwest of Dabeiba, on the old State farm of the Antioquian government, which deeded the land to the Federal government for a rubber experiment station and demonstration plantation.

During 1942 and 1943, several shipments of rubber seed were sent to these Colombian nurseries by the United States Department of Agriculture from Brazil, Honduras, Costa Rica, and Panama. Budded stumps of high-yielding clones, to supply budwood for budding the resultant seedling nurseries, were supplied from the Department's multiplication center at Tela, Honduras. A summary of the history and progress of the program through 1944 was published by Sorensen (*88*).

The original schedule of field planting at each center had to be reduced by 1945, because of a shortage of skilled supervision, inadequate multiplication of the Eastern clones because of delay in controlling leaf blight, and transportation difficulties. Under the revised program, 21 hectares out of a planned 100 were planted at Acandi, 33 hectares of 130 at Turbo, 5 out of 200 at Rio Grande, 3.5 out of 53 at Apartado, and 64 of 400 at Villa Arteaga.

Postwar adjustments and shortage of funds prevented extension of the highway on which the lower valley centers were to be dependent for their full development. Therefore, those plantings at Turbo, Rio Grande, and Apartado were retained on a maintenance basis, and all subsequent activities have been concentrated at Villa Arteaga, where the new highway (Carretera al Mar) reached some years ago.

Villa Arteaga Rubber Station

In mid-1943, the well-known Colombian agronomist Rafael Rivera was assigned by the Colombian Government to develop the farm at Villa Arteaga into an experiment station and demonstrational center for rubber. He was joined by H. G. Sorensen, of the United States Department of Agriculture, who first obtained a large quantity of wild rubber seed from the Amazonian area near Leticia for the multiplication gardens. Resistant clones for topbudding were introduced from Costa Rica, and initial field experiments were planted. Upon the retirement of Rivera, the Caja de Credito Agrario assigned Fabio Gutierrez as agronomist and director of the station. He was succeeded in 1952 by the present director, Jesus Franco. During the period 1943–49, important technical aid was given by two scholarship trainees of the United States Government, Alfonso Uribe Henao and the late Frank A. Sierra Soto, who had been assigned to the regional rubber station and Inter-American Institute of Agricultural Sciences, Turrialba, Costa Rica, and to the University of Missouri, respectively. In 1950, Uribe (*96*) published an article on the technical aspects in the production of hevea rubber. That, among others, furnishes essential information for the training of additional Colombian agronomists, of which there is continuing need on the rubber prgram.

With the technical assistance of H. G. Sorensen from 1942 to 1945 and of his successor, W. Mackinnon, in 1946 and 1947, the first plantation unit of 109 hectares (269 acres) was planted. Successive plantings by years are listed as follows:

Year:	*Area (hectares)*	*Trees (number)*
1947	109	46, 123
1948	119	33, 702
1950	20	3, 177
1951	12	1, 363
1952	11	6, 222
1953	47	24, 500
Total	318 (788 acres)	115, 087

After 1948, a reduced budget, difficulties in obtaining seed for rootstocks, and other problems, including change of directors in 1952, have slowed the rate of planting. According to reports by R. E. Stadelman, who has represented the United States Department of Agriculture since December 1949, a cessation of field planting beyond that already authorized has been ordered until yield data are obtained from existing plantings. In addition to new clone tests involving interplantings of coffee and cacao and other minor plantings, Stadelman has recommended the establishment of additional governmental or private pilot plantations as the intermediate goal toward development of a small-farm industry. The Villa Arteaga station scheduled a nursery production of 100,000 trees for some 375 acres previously authorized for planting in 1954. Through continued cooperation with other countries and annual receipt of new clones from the coordinated breeding program to test for local adaptability, Colombia now possesses the essential knowledge and experience to expand plantation rubber production.

According to W. Mackinnon, regional plantation management adviser, who has inspected operations periodically, the soundly developed rubber plantings at Villa Arteaga represent a valuable step forward in the future economy of Colombia. By the end of 1954, some 30,000 trees will be ready for commercial production and should yield some 45,000 kilos of dry rubber in 1955. As more areas are brought into production, yields will increase, and, as cash returns materialize, private interests and small farmers will probably become interested in the crop.

Immediate efforts, according to Stadelman, will be made to reduce costs of rubber production and to test more efficient methods. Such a program should provide a sound basis for future expansion of planting on the 95,000 hectares of reserve lands in the Uraba region. The completion of the highway through this region was scheduled for June 1954.

Costa Rica

Background

One object of the 1940 rubber survey, conducted under bilateral agreements with some 15 countries of tropical America, was to determine what country or countries best combined the requisite conditions for attacking several major problems, particularly South American leaf blight, that had hitherto prevented successful rubber production in this hemisphere. Research to gain a better understanding of leaf blight demanded an environment in which the disease would be active and virulent throughout the year. This environment also would be advantageous for determining the resistance, or susceptibility, of new progenies produced in the breeding work in nearby blight-free areas. While the disease had been epidemic in several Amazonian countries, as for example on the Ford plantations of Brazil, the occurrence of a prolonged annual dry season and complication from other diseases, such as target leaf spot, made judgment of true resistance to leaf blight in nursery plots somewhat uncertain within the first year. Although preliminary selection could be made for disease resistance among the annual breeding progenies in Brazil, a quick and more certain test was needed for selections to be distributed to other countries.

These biological requirements, plus easy accessibility by rail and highway and a climate suitable for research, were encountered on the Atlantic slope of Costa Rica at the town of Turrialba, at an elevation of 2,000 feet, some 40 miles from the highland capital of San José.

Establishment of Regional Station

The establishment of the regional research station at Turrialba was begun in 1940, in cooperation with the Costa Rica Government. The station has been operated and, for the most part, financed by the United States Department of Agriculture through the Rubber Crops Section (formerly Division of Rubber Plant Investigations).

Under a formal intergovernmental agreement (*95*), effective June 16, 1941, the Republic of Costa Rica purchased 80 acres of land near the town of Turrialba for the research headquarters, for progeny testing and selection nurseries, and for permanent clone collections; and a 1,900-acre abandoned banana farm "Los Diamantes," on the north coastal plain near the town of Guapiles, for large-scale hevea field experiments. Realizing the importance of the work to be undertaken, the Costa Rica Government, through successive administrations, has made substantial direct and indirect contributions to station operations (table 1).

In a small private rubber planting near the Turrialba headquarters, South American leaf blight had been found in 1935, and its continuing severity in 1940 showed that climatic conditions were ideal for the disease research and selection work. Therefore, the first nursery, planted in September 1940 under supervision of H. F. Allard, was thoroughly invaded the following year by the blight.

In September 1941, T. J. Grant, an experienced pathologist, was assigned to develop the station and research projects. In November 1941, M. H. Langford, who had conducted initial spraying experiments on the Goodyear plantation in Panama, was transferred to Turrialba, which location was more favorable for further experiments and for basic studies of the disease. In December 1942, the disease research was further augmented by the appointment of E. P. Imle, who, after the resignation of Grant in 1945, continued as director of the station. From 1941 to 1954, Grant and Imle brought the station and its field projects to the full status of an international institution on rubber that has been so recognized by the governments of cooperating countries.

Langford (*35*, *37*) demonstrated practical and effective control of leaf blight by fungicidal sprays in nurseries and in young field plantings prior to topbudding with resistant strains. He set up a practical and reproducible system of plant classification, symbolizing the particular degree of resistance or susceptibility to the disease, of all material in the testing and selection program. A number of crown clone selections that tentatively had been considered resistant in Brazil did not stand up under the more severe conditions at Turrialba.

Control of leaf blight at Turrialba by the combination of spraying and topbudding with resistant strains formed a sound basis for the large-scale commercial topbudding of the first plantings of susceptible Eastern clones on the Speedway estate of the Goodyear Rubber Plantations Co. at Cairo, Costa Rica. The continuous cooperation of this company, through its director of research, the late W. N. Bangham, and successive local managers, W. E. Klippert, L. O. Figland, H. N. Lundberg, and H. Echeverri, and by its financing of large-scale experiments on disease control and other studies, has saved the United States Department of Agriculture many thousands of dollars and contributed much information toward successful establishment of a rubber-producing industry in tropical America.

Cooperation of Bolivia, Brazil, Colombia, and Peru enabled shipment of large seed collections and individual selections from jungle exploration work to Turrialba for resistance tests. In later years, primary selections from the cooperative breeding program of the Instituto Agronomico do Norte (IAN) at Belterra, Brazil, were also distributed to Turrialba for critical resistance tests. The more promising of these selections, after planting in a local "clone museum," were then further distributed to the cooperative breeding stations at Cuyotenango, Guatemala, and Marfranc, Haiti, respectively. These stations, without the complication of leaf blight, could then use these clones for backcrosses and other combinations involving Eastern clones. The resulting seed could be sent to Costa Rica for disease-resistance tests and the better selections from the resulting seedling progenies could be distributed to Brazil and other cooperating countries.

Los Diamantes Substation

As selections became available at Turrialba for replicated yield tests, the Los Diamantes farm near Guapiles was developed. The first series of field-plot experiments involved plantings of resistant jungle selections and others from nursery seedling populations from this source. Then, it was urgent to determine the yield of well-known Eastern clones as influenced by each of a large series of resistant crown clones that had been recommended for topbudding in Brazil. Factors of compatibility, vigor, shape, and size of the crown were recognized as probably influencing the dry rubber content (DRC) of latex as well as total rubber yield of the midtrunk, or panel clone. Field plantings to determine such influences and for evaluation of the various trunk-crown combinations were established.

Since interplanting of rubber during the first 3 years with food crops is important to a small-farm industry, an experiment comparing 6 spacings of rubber rows with interplanting of such crops as corn, cassava (yuca), taro, beans, pineapple, and sugarcane was laid out.

During the decade, 1942–52, some 20 comprehensive field experiments were planted at Los Diamantes and 18 smaller ones at Turrialba. Among the latter are notable experiments involving permanent mixed plantings of rubber with coffee and rubber with cacao that have attracted hemisphere-wide attention in recent years.

Hevea may be substituted for the usual coffee-shade trees (of no cash value in themselves) throughout the median altitudes (1,500 to 2,200 feet) that are not too low for varieties of *Coffea arabica* L. and not too high for good yields of hevea, although requiring a somewhat longer period to reach tapping size. In this altitudinal zone of Central America, land is usually expensive and the population is sufficiently large to assure the handling of two partial crops from the same land, with probably a much greater combined cash return per unit of land than from either crop grown separately.

Except for a 2-year absence in 1945 and 1946, during part of which period C. E. Maki was in charge, development of the Los Diamantes substation was directed continuously from November 1942 to June

1954 by W. E. Manis, agriculturist. From July 1951, he was assisted on tapping and rubber preparation by A. V. McMullan, chemist. At both Los Diamantes and Turrialba, the following Costa Rica employees of the United States Department of Agriculture have contributed long periods of valuable service as field superintendents or laboratory and office assistants: Arturo Lizano, now a director of the Banco de Seguros, Edwin Padilla at Los Diamantes, now with the Venezuelan Government, and Edilberto and Enrique Camacho, employed as scientific aid and farm superintendent, respectively, at Turrialba. Rands (*65*) in 1945 outlined the founding of the Costa Rica projects and major research objectives, and Grant (*27*) summarized progress to 1946.

Outbreak of Phytophthora Leaf Fall

Before most of the above-mentioned field experiments had reached the usual size for tapping and determination of rubber yield, epidemics of phytophthora leaf fall began, and, since 1950 the disease has recurred annually during the wet season. Although long recognized in Costa Rica as the cause of cankers, or black stripe, on the tapping panel and in Southeast Asia and Brazil for occasional leaf fall, the sudden and seriously defoliating damage by *Phytophthora palmivora* at both stations in Costa Rica and on the Goodyear plantation has been difficult to explain. One theory is that a mutant or new strain of the fungus, particularly virulent on leaves and branches, has appeared in Costa Rica and multiplied to epidemic proportions. J. B. Carpenter was transferred from Peru to Costa Rica in 1950 to study *Phytophthora* in Costa Rica, and he published his results in 1954 (*20*).

Practically all of the topbudding clones recommended up to 1950 as resistant to South American leaf blight are reported by Manis to be susceptible to the leaf fall. Thus, any yield comparisons in earlier field experiments topbudded with these clones have been at least partly vitiated. Fortunately, however, among the hundreds of miscellaneous blight-resistant selections growing in the "museum" plots and field experiments at both Turrialba and Los Diamantes, 11 selections have been found combining acceptable resistance to both South American leaf blight and phytophthora leaf fall, with the requisite secondary characters demanded of crown clones. Most of these are interspecific hybrids between certain selections of *Hevea benthamiana*, which are resistant to *Phytophthora* and nearly immune to leaf blight, and susceptible high-yielding Eastern clones. The history of this *Phytophthora* epidemic and selection for resistance are described by Manis (*49*). Striking differences in susceptibility to leaf fall are shown in figure 8.

Defoliation and dieback resulting from phytophthora leaf fall in nurseries have been controlled with the same fungicidal sprays used for controlling the leaf blight. However, the lesson from this Costa Rican experience is that henceforth all rubber plantings in similarly wet areas throughout tropical America must be protected by topbudding with the new clones that are resistant to both diseases.

The newer Costa Rican field experiments and small-farm plantings have been either rebudded or planted originally with trees having these superior tops. The somewhat older commercial areas of the nearby

FIGURE 8.—Topbudding clones susceptible and resistant to phytophthora leaf fall in Costa Rica. The center row was topbudded with F 1619, which is resistant to South American leaf blight but highly susceptible to phytophthora leaf fall. On left and right are topbuddings of FX *benthamiana* hybrids displaying resistance to both diseases.

Goodyear plantation, although having a mixed canopy of *Phytophthora*-susceptible clones, have been able to continue in economic production. Admittedly, however, during those seasons of unusually high rainfall, yields have been reduced because of tree defoliation. For all replanting and new planting, the *Phytophthora*- and blight-resistant new clones are being used for top-budding.

Through cooperation of the Goodyear Rubber Plantations Co., their extensive new nurseries have provided an opportunity for testing new spray fungicides. In a recent publication, M. H. Langford and H. Echeverri (*41*) report superior control of South American leaf blight with Dithane Z–78 or Parzate applied at 8-day intervals. These fungicides proved more effective than applications of an insoluble copper fungicide (previously the standard material for control of leaf blight) at 4-day intervals. The use of Dithane or Parzate for spraying hevea nurseries has been extended to many localities, and in South America these fungicides have been reported to give superior control of both leaf blight and target leaf spot, the two most destructive diseases.

Carpenter (*19*) has recently summarized extensive tests conducted at Turrialba and Los Diamantes in the screening of fungicides for control of black stripe of the tapping panel, caused by *Phytophthora*. Studies and observations on other miscellaneous diseases of hevea in Costa Rica have recently been published by Carpenter (*18*), Carpenter and Stevenson (*22*), Langford (*40*), and Stevenson and Imle (*90*).

Concentration during the earlier years on urgent disease problems postponed attention at Turrialba and elsewhere to important physiological problems that arose in connection with topbudding as well as the more intimate relationship of panel clone to crown clone. An appreciation of the latter problem may be gained from figure 9, *A*, which shows the striking differences in latex flow from knife pricks made above and below the union of a low-yielding top clone and a high-yielding Eastern clone, respectively. The use of interspecific hybrids for top clones, as mentioned above for *Phytophthora* control, introduces another possible influence on total yield and dry rubber content of latex of the panel clone. Figure 9, *B*, for example, illustrates a highly incompatible top, F 6395, which is a hybrid between *H. spruceana* and *H. brasiliensis*. Topheavy trees with this clone have suffered severe breakage in wind storms.

Many extremely vigorous but otherwise useless hybrids have been encountered among the breeding progenies. If these could be utilized as clonal rootstocks on which to basebud the high-yielding clones, it is conceivable that, by virtue of their great vigor, field plantings might be brought into production a year earlier, even on the poorest soils. Such rootstocks could only be obtained as rooted cuttings but in spite of considerable prior research, the rooting of clonal material has proved extremely difficult. Whereas branch cuttings have given very poor results in rooting trials, cuttings from seedling stems root readily.

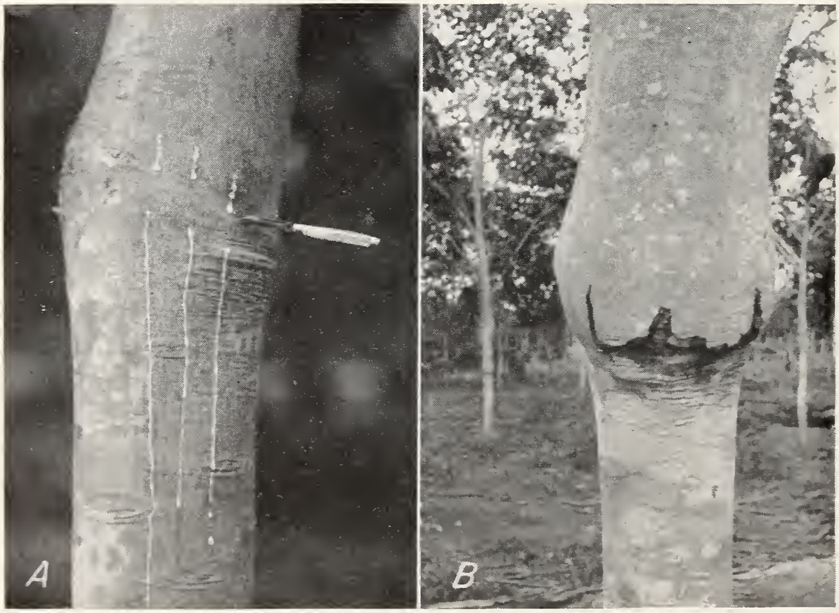

FIGURE 9.—*A*, A 2½-year-old topbud union of a compatible low-yielding but blight-resistant crown clone topbudded on a high-yielding Eastern clone. Wide difference in yielding capacity is indicated by comparative latex flow following knife stabs. *B*, An incompatible crown clone, F 6395 (hybrid of *Hevea brasiliensis* × *H. spruceana*), topbudded, on an Eastern clone on the Belterra plantation, Brazil.

The responsible "juvenility" factor may be maintained through several vegetative generations, provided these are made at frequent intervals and with buds only from the primary stem of the budding.

To study these and related problems, Luis E. Gregory was assigned to Turrialba from August 1948 to May 1952. In a preliminary report in 1951 (*28*), he gave a method that, for the first time, produced some rooting of cuttings of Tjir 1, which is one of the oldest Eastern clones. Then in 1953, in collaboration with Imle and Camacho, he (*29*) reported favorable results from stem wrapping, to solve the practical problem of tree survival after transplanting 3-component trees.

Following departure of Gregory for further university training, A. M. Dycus was assigned from 1952 to 1954 to continue the physiological projects. To direct these and a basic research on precursors of the rubber hydrocarbon, M. W. Parker, an experienced physiologist, was transferred to the rubber program in March 1952. Upon retirement of R. D. Rands in December of that year, Parker was appointed Head of the Division (now Rubber Crops Section) and continued until 1954 (termination of the program) to direct the researches that are basic to a successful industry.

Commercial Rubber Plantings

As a result of the epidemics of phytophthora leaf fall since 1950 and the necessity for selecting and testing new crown clones resistant to both it and leaf blight, E. P. Imle, director of the Turrialba station, slowed up the small annual tree distribution plan then in effect until new crown clones could be selected.

Planting in 1953 was restricted by the station to cooperative experimental plots in strategic locations, but Imle has reported that further tests and experience of that year proved that the new topbudding clones had a commercially adequate level of resistance to *Phytophthora.* These clones now have been multiplied and distributed, and further commercial planting can be resumed. Imle and Manis also have reported important new areas in the lower General Valley of Costa Rica as being promising for future rubber plantings with fewer disease problems than in the Atlantic Zone.

Dominican Republic

Background

The Government of the Dominican Republic issued a formal invitation, and that country was included in the rubber surveys of Latin America in 1940–41. The survey party, consisting of R. J. Seibert, botanist, R. C. Lorenz, plant pathologist, M. Striker, soils specialist, and H. G. Sorensen, rubber technologist, was joined by R. D. Herrera, agronomist of the Dominican Secretariat of Agriculture. During March 1941 the principal districts having climatic conditions suitable for growth of hevea were visited, and the topography, soils, and other features examined.

While the Republic lies between parallels 17°40′′ and 20° north latitude, wholly within the tropical zone, it is very close to the northern limit of what has been considered the belt in which hevea can be grown commercially. Nevertheless, small test plantings of hevea made in 1932 by The B. F. Goodrich Co. at altitudes of 450 and 950 feet proved that the tree could be successfully grown under those conditions.

Deficiency of rainfall (annual precipitation below 70 inches) was found to be a more limiting factor. Adequate rainfall for economic rubber production occurs in a relatively small part of the Republic. Three general areas were found having the proper conditions: (1) Province of Duarte and the eastern part of the Province of La Vega; (2) Province of Samana, and (3) the north coastal strip of Seibo Province. In recent years the Provinces of Puerto Plata and of Monte Cristi also have been found to contain some suitable areas.

Only a part of these general areas is suitable for rubber growing because of local variations in rainfall, soils, and the mountainous nature of a large part of these districts. Nevertheless, with proper selection of sites, the survey party estimated that at least 100,000 acres could be found that were available for such use.

On June 24, 1941, an interagency agreement was signed by the Secretary of State for Agriculture, Industry, and Labor of the Dominican Republic, and by the Chief of the Bureau of Plant Industry, United States Department of Agriculture, authorizing cooperative research and rubber development projects to encourage establishment of a producing industry. Since the country has a labor shortage and is characterized in the more developed areas by many small farms interspersed with large haciendas, the Dominican Government emphasized a small-farm, or single-family, type of rubber production. Self-sufficiency in the product was another aim, since increasing imports from Southeast Asia would have to be made for local tire recapping and other rubber industries.

Establishment of Piedra Blanca Station

In 1941, headquarters for the rubber project were established near the village of Piedra Blanca on the Duarte Highway 45 miles northeast of Ciudad Trujillo. Here, as mentioned earlier, had been planted in September 1932 one of the test plots of the B. F. Goodrich Co. This plot contained about 270 mature hevea seedling trees in 1941. A second plot was established 3 miles to the south at an altitude of 950 feet above sea level. This second and less developed planting contained 230 trees.

Investigation by the Goodrich Company

The Goodrich company plantings originated from jungle seed received by the company from the far southern range of *Hevea brasiliensis* in the State of Mato Grosso, Brazil, and exported via Rio de Janeiro to the Dominican Republic. Reddish or purplish inner bark commonly found in jungle trees in the Mato Grosso area was believed to be correlated with a superior quality of rubber. Therefore, selection work among seedling populations might discover trees combining the character with resistance to South American leaf blight. However, leaf blight has not appeared in the Dominican Republic nor in adjoining Haiti, and the chances are good for its permanent exclusion.

Since the research objectives of the Goodrich company coincided in part with those of the official cooperating governments, an agreement was reached permitting detailed study of the trees, including resistance tests in Costa Rica on any selections, as well as utilization of the annual seed crops for local rootstock nurseries. Later the company kindly expanded to 100 acres its land lease with the Banco de Reservas to include both plots of rubbertrees, with an area between these and the Duarte highway.

During the period from January 1943 to October 1948, the United States Department of Agriculture was represented by H. F. Allard as technician on the research and development program at Piedra Blanca. Budded stumps of high-yielding Eastern clones were imported from the cooperative station at Marfranc, Haiti, and later in 1943, some 300,000 seed were shipped by the Department from Mexico to start immediate nurseries. In most subsequent years, the mature Goodrich trees yielded from 60,000 to 100,000 seed that likewise were used.

The Secretary of State for Agriculture, Industry and Labor, Huberto Bogaert, took an active interest in the project, and through his assistant, Juan P. Duarte, agronomist, directed the distribution of part of the seed to some half dozen provincial agricultural farms, or stations, which were to serve as local plant-material multiplication and distribution centers. The superintendents of these "campos" were given a training course in budgrafting and other operations at Piedra Blanca. Seed was also given to a number of large landowners who had made hasty plans for planting sizable areas of rubber, without informing themselves about the complications and cost involved with this new long-term crop.

Very few seedlings in these early nurseries were ever successfully budded, and Piedra Blanca continued as the chief source of high-yielding material in the Dominican Republic. By 1945, more than 100,000 plants were available, and this was the first year of large-scale budded stump distributions. A start was made on a 20-acre clone garden and other experimental plantings. A residence-office building and other structures were erected, including a factory shed for coagulating pans and hand-sheeting machines used to handle latex from further test tapping of the Goodrich trees and to serve as a model small-farm rubber preparation demonstration. Miguel A. Garcia R., agronomist, was placed in charge of the station and served continuously until early 1953. During most of this period, he was assisted by R. Astwood, who had been the caretaker of the Goodrich plots.

During the period from 1945 to 1951, budded stumps were distributed to several hundred farmers of small- and medium-size plots in the provinces mentioned above, but especially in that of La Vega where the station was located. Unfortunately, as in several other cooperating countries, trained assistance to supervise the planting and continued care of these widely scattered and often difficult to reach ½- to 10-acre areas proved wholly inadequate. A large percentage of them undoubtedly have since been abandoned. Several inspected by the senior writer in 1952 had been given some care and showed normal development, but had not been pruned during the first year so that a large percentage of twin and even triplet trees, originating as sprouts from the low-yielding rootstock (instead of one only from the implanted bud) were encountered.

The lesson here again proves the inadvisability of rapid expansion by the usual extension procedures of a new crop involving the complications of budded hevea before the essential know-how has permeated each community through a few carefully supervised pioneer enterprises. Therefore, not until some of the older 3- to 5-acre plots are put into tapping and the proprietors themselves see the cash return realizable from rubber sales, will there be any keen interest in the crop among small growers.

The unique origin of the 500 trees in the 2 Goodrich plots at Piedra Blanca warranted detailed study of yield and possible leaf blight resistance. On the basis of 2 preliminary test tappings in late 1939 and early 1940, supervised by W. D. Stewart of The B. F. Goodrich Co., branch budwood of 7 of the highest yielders, representing both white- and red-bark types, was dispatched in August 1942 by H. G. Sorensen to Turrialba, Costa Rica. These numbers were established there as clones and planted in the leaf blight testing nursery.

At the end of 1943, M. H. Langford summarized the leaf blight ratings: All but No. 5, which was lost, showed moderate to extreme susceptibility (ratings of 6+ to 10++++). No. 1, the highest yielder, which was noted to have white bark but yellow latex, had the rating of 6+, which is marginal for commercial use. Nevertheless, it was transplanted to the museum collection for further observation and later test tapping as a clone.

In late 1942, Sorensen sent a consignment of seed collected from plot No. 1 (at 450 feet elevation) to the Costa Rica station for a seedling population appraisal on blight reaction. Some 4,000 seedlings were obtained, and during the following year 33 were selected and assigned Tu (Turrialba) numbers for transplanting and preservation in the clone museum. The seedling population, as a whole, showed extreme susceptibility and practically all of these selections displayed only marginal tolerance to the disease. In further records from the Turrialba station in November 1948, R. J. Seibert noted that all of these selections were characterized by spindling and very slow growth, with annual girth increases of only one-third to one-half that of most clones in the collection.

Since the original seed for the Dominican plots came only from a very small area in the State of Mato Grosso, Brazil, these disease and selection studies may not be representative of all native *Hevea brasiliensis* throughout that large area.

Recent Developments

Since 1951, the Dominican Government has planned on including rubber in the two colonization projects in the Samana Peninsula area, known as Colonias "Majagual" and "Rancho Espanol." According to reports on inspection trips in February and September 1952 by W. Mackinnon, regional plantation management adviser of the United States Department of Agriculture, this new area has excellent possibilities for the development of agricultural crops such as coffee and rubber, both long-term crops that tie the farmer to his land.

Assuming natural rubber requirements within the country over the next 10 to 15 years may approach 2,000 tons, Mackinnon suggested a 5-year program of planting from which half this quantity would be produced on small farms and the other half on larger plantations. This would require 1,500 hectares of small-farm plots and 1,000 hectares of larger plantations.

Four hundred hectares of the "larger plantations" should consist of two government demonstration areas of 200 hectares, each, centered (1) in the Samana Colonization area, and (2) as an extension of the 25 hectares of experimental plantings at Piedra Blanca. These demonstration units would (1) be of economic size and self-supporting, (2) assure a local supply of natural rubber, (3) serve as training centers for graduate agronomists and extension agents, (4) multiply plant material for distribution to small farmers in each region, and (5) serve as processing and packing centers for rubber produced by small farmers in the vicinity.

Total estimated cost of the 5-year plan, including the supplying of small farmers with 57,000 plants at 10 cents per plant and developing 1,000 hectares at $700 per hectare, was calculated at $757,000 (excluding cost of land and interest on capital). At full maturity (10 years), the larger plantations at least should yield 1 metric ton per hectare annually.

Increasing production of high quality clonal seed from certain of the station areas since 1948 has resulted in the recommendation that henceforth only topped clonal seedlings be distributed to small farmers, thus reducing the amount of supervision previously required when budded material was used.

Following the departure in 1948 of H. F. Allard, periodic assistance has been rendered the Dominican program by A. W. Bechtel, head of the regional breeding station at Marfranc, Haiti. Also from January 1952 to July 1953, D. D. Albert served as resident extension agent under the direction of Messrs. Bechtel and Mackinnon.

For budgetary reasons the above 5-year plan was not adopted by the Dominican Government, and, although it is understood that collection of clonal seed has continued for distribution to farmers of small acreages by the district extension agents who were trained at the station, technical assistance on rubber was discontinued by the United States and the cooperative agreement was canceled.

Guatemala

Historical

Interest in rubber production in Guatemala extends back to the early years of this century, when the native *Castilla elastica* Cerv. was widely exploited. Extensive plantings of this tree were made in response to the terms of a law, passed in January 1899, offering grants of land for such plantings and their maintenance during the first 4 years. However, rubber exports declined from 239 tons in 1900 to 2 tons in 1923.

From a survey during 1923–24 made by Treadwell, Hill, and Bennett (*92*), important facts and features of the country from the standpoint of rubber growing were reported. They listed mainly parts of the Peten and of Motagua Valley—and not the west coast—as areas suitable for the culture of hevea.

Cooperative Program

In September and October of 1940, upon official invitation of the Guatemala Government, a survey party from the United States Department of Agriculture, consisting of C. B. Manifold, rubber technologist, T. J. Grant, pathologist, T. D. Mallery, botanist, and R. E.

Stadelman, agriculturist, inspected these and other promising districts under guidance of local officials and interested plantation companies. Attention was focused on the west coast region because of its accessibility, abundant population, topography, soils, and climate. Because of climate, specifically rainfall deficiency, the region had not been considered favorable for hevea by the earlier survey party. While such was found to be true for the coastal areas, more detailed study of rainfall records revealed definite precipitation zones, and that a belt lying between 500 and 2,500 feet elevation offered ample rainfall and other conditions satisfactory for hevea culture. Below this belt, extending from El Salvador on the southeast to the Mexican border, the dry season is too prolonged and severe, and above 2,500 temperatures are too low for commercial development of hevea.

On June 23, 1941, a cooperative agreement authorizing a rubber project was signed by the Secretary of Agriculture of Guatemala and the Chief of the Bureau of Plant Industry, United States Department of Agriculture. Upon its expiration in June 1951, cooperation was continued under a more general intergovernmental agreement of 1944, especially the supplement of 1945 in which work on rubber and other agricultural projects was authorized.

Establishment of Rubber Station

A rubber plant multiplication and distribution station was established in 1942 on 70 acres of land belonging to a west coast plantation, Hacienda Trapiche Grande, at an altitude of 800 feet. The station is about 3 miles south of Cuyotenango, which is on the railway and also on the Inter-American Highway between Guatemala City and Mexico. In August 1947, an additional 47.5 acres were added to the station from adjoining pasture, making a total of 117.5 acres in the station farm. The land has been furnished for an annual token payment of $1 as a public service by its owner, L. Lind Pettersen, who planted some 900 acres of hevea on adjoining areas of his plantation. The valuable assistance rendered by Mr. Pettersen through the years has been appreciated and acknowledged by representatives of the cooperating governments.

A detailed report on the survey and progress, including development of the cooperative station through 1945, was presented in 1946 in a processed publication (*45*) in both Spanish and English. Up to that time, several million rubber seeds had been furnished by this Department from Honduras and Mexico for rootstock nurseries, and several thousand budded stumps of high-yielding hevea clones were planted at the station and at several secondary multiplication centers to meet the widespread demand for planting material. This demand came mainly from owners of medium-size to large farms who had available land in the "rubber zone" and who wanted to diversify their farming by supplementing coffee with another cash crop.

The United States Department of Agriculture in 1941 requested E. T. Stanwood, horticulturist in charge of the temporary station at Tela, Honduras, to organize the Guatemala project. In order to meet widespread requests for information on the new crop, Stanwood and Antonio Toruno (representing the Secretary of Agriculture of Guatemala) in 1942 published a booklet on the cultivation of hevea in Guatemala (*89*). In May 1942, Stanwood's assistant, J. F. O'Donnal, was transferred to Guatemala to take over detailed direction. Since that time, O'Donnal has been in charge of the project and has been aided by several assistants.[5] In 1944, L. A. Beery, Jr., was transferred from Brazil to serve as advisory group leader for projects in Guatemala, El Salvador, Honduras, and Nicaragua. He served until December 1947, having completed establishment of initial breeding gardens and yield tests. During 1945, several more carefully controlled experiments and clone collections were planted on the station farm.

Progress in Commercial Planting

By the end of the 1944 budding and planting season, 1,315 acres of field plantings on 16 farms in Guatemala had been established. The rubber areas ranged in size from 5 to 704 acres. On farms of the larger cooperators, such as the 500 acres of rubber planted by the United Fruit Co. at Bananera, Motagua Valley, several yield tests and other experiments were included in the commercial plantings.

Small-Farm Program Inaugurated

Under the new agreement of 1945, which established a general agricultural experiment station in Guatemala City, known as the Instituto Agropecuario Nacional, the Guatemala Government authorized the new station to sponsor a small-farm rubber planting program with an initial budget of $5,830 for 1946. This continuing program, provided for the distribution of budded stumps of high-yielding Eastern clones, free of charge, to plant a maximum of 5 acres each by responsible small-farm cooperators. However, in 1954, the government began charging for plants at 3 cents each. Small farmers are able to obtain loans from Agrarian Credit Bank for planting and bringing their areas into production. Technical guidance of this program, including the supervision of the Guatemala agronomist in immediate charge, was assigned to the United States rubber technicians at the Cuyotenango station.

By 1953 total rubber plantings had reached about 2,000 acres, as listed in table 1. This acreage was distributed among 11 large landowners, with a total of 1,895 acres (1,100 acres of tappable size), and some 35 small farms, with a total of 137 acres in rubber. About 35,300 trees, some on large holdings and some on small holdings, were in production or being prepared for tapping.

Experience throughout the west coast rubber zone has demonstrated that, because of the sharp dry season, field-planted trees have never been seriously damaged by South American leaf blight, and, therefore, topbudding with resistant strains, as practiced in the earlier years, is no longer necessary. This has removed a delaying handicap to rapid expansion of both types of plantings.

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[5] In 1943, O'Donnal was assisted for part of the year by another technician, E. J. Vrana. The Guatemalan agronomist, Jose T. Coronado, was appointed station field superintendent and Mario Bernard, assistant. In 1944, Arvid Royne took charge of budding operations on the cooperating plantations. Following resignations in late 1944 of Vrana, Bernard, and Royne, Vitelio Acuna and Carlos E. Galvez were appointed and rendered important services on the program until December 1948 and May 1950, respectively.

The availability of high-yielding clonal seed from station plantings, both in Guatemala and Haiti, helped the plant-material multiplication program, especially for small farmers. Earlier plantings of 6 small-farm operators were ready for production in 1952, and the enthusiasm of those proprietors for the crop, plus encouragement by the Guatemala Government under its new agrarian law, brought widespread requests for planting material. Thus, in 1953, an additional 86 small growers applied for clonal seedlings.

For supervision of the expanded program, the Guatemala Government assigned 2 permanent and 8 temporary agronomists to the Cuyotenango station to assist Mr. O'Donnal. In March 1954, 2 additional local agronomists were permanently assigned to the station. Expansion of new plantings and thinning and tapping demonstrations in the older ones were scheduled for 1954. From the extensive new nurseries it was hoped to comply, in part at least, with requests from 392 additional small-farm operators and 4 from large farmers wanting to plant from 50 to 200 acres, each. Following departure of Mr. Beery in 1947, the larger rubber growers have sought experienced advice on cost estimates, scheduling of operations, factory purchase, and rubber processing from 2 succeeding regional plantation management advisers, W. Mackinnon and H. C. Haines.

Development of Regional Breeding Project

The sudden appearance in late 1948 of South American leaf blight (apparently wind-borne from infected areas in Mexico) at the station and other nurseries on the west coast, and its then unpredictable effect on field trees, temporarily delayed plans for a breeding program to be integrated in an overall project apportioned to the stations in Haiti, Costa Rica, and on the Belterra plantation of the Instituto Agronomico do Norte in Brazil. However, as stated above, the disease did not seriously affect field-spaced trees of susceptible Eastern clones and, by 1951, the original breeding objectives utilizing these clones were resumed.

J. E. Shrum, Jr., geneticist, was assigned in May 1951 to the Cuyotenango station to develop the breeding program and take charge of all agronomic experiments on rubber.[6] The particular phase of the breeding program to be stressed at Cuyotenango involved establishment of open-pollinated seed gardens to obtain backcross and outcross progeny from the new and very promising disease-resistant hybrid clones furnished by the Instituto Agronomico do Norte at Belem, Brazil. In order to hasten such seed production, some 20 acres of the earliest mature trees with ample tapping records, were pollarded and topbudded with the new clones. The arrangement of the resistant hybrids and susceptible Eastern parents was designed to encourage natural cross-pollination between nearly 200 of the resistant BC_1 hybrids and strategically located high-yielding but susceptible Eastern clones. This arrangement also will aid in parental identification of the resulting seed. Crownbudding will be completed in 1954, and the first appreciable seed production is anticipated by 1957. These are

[6] Shrum succeeded A. V. McMullan, chemist, who supervised station tapping and rubber-preparation demonstrations during the period October 1949 to July 1951.

the only breeding gardens in the Western Hemisphere containing the requisite materials for obtaining relatively soon a further and most valuable breeding generation.

From April 1951 to August 1953, C. N. Hittle, regional geneticist from Costa Rica, coordinated the special breeding project in Guatemala with other phases of hevea improvement in Haiti and Costa Rica. He, in turn, received special counsel from the experienced geneticists, W. M. Myers, now at the University of Minnesota, and H. M. Tysdal, of the United States Department of Agriculture.

Firestone Experiment Plantation

An earlier section of this circular describes the 200 acres of Madre de Dios seedlings planted during 1949 to 1954 by the Firestone Plantations Co. on its 240-acre farm in Guatemala (p. 17). This and other projects were authorized, with approval of the Guatemala Government, in a cooperative agreement of 1948 between this company and the Bureau of Plant Industry, Soils, and Agricultural Engineering. The objectives are: (1) To develop disease-resistant and superior hevea clones through tests of seedlings derived from native populations of the Amazon Valley; (2) to determine the comparative merits and local adaptability in Guatemala of new hybrid clones produced locally or in other parts of the Western Hemisphere; and (3) to conduct other work for the encouragement of Latin American rubber production.

The plantings under major objective 1, occupying 200 acres, represent the first adequate test under cultivation of the supposedly superior strain of *Hevea brasiliensis* found in the highland jungles of Madre de Dios; Peru; Acre Territory of Brazil; and possibly in the Beni and Pando Provinces of Bolivia.

Progress has been made on the other objectives, including careful yield tests of new selections, for which space was lacking at the Cuyotenango station. This cooperation by a private company, extending through the necessary period of years, will have saved the cooperating governments several hundred thousand dollars and will have contributed information and plant materials of inestimable value to the natural rubber industry.

Haiti

Background

Upon official invitation by the government of Haiti, the United States Department of Agriculture included Haiti in its 1940–41 survey to determine Western Hemisphere areas suitable for the production of rubber. The survey party, consisting of O. D. Hargis, rubber technician, H. G. Sorensen, soils specialist, R. J. Seibert, botanist, and R. C. Lorenz, pathologist, was joined by several Haitian district agronomists. This party surveyed the principal districts, held official conferences, and agreed upon a plan of cooperation between the respective Departments of Agriculture.

Haiti is situated just below latitude 20° north and, for this reason, has been considered as probably marginal for hevea rubber production. Nevertheless, a survey published in 1926 by the United States Department of Commerce (*92*) recommended the country be given consideration for a peasant-type of rubber production. A major factor for this recommendation, and the continuing interest in the country, was the satisfactory growth of an existing hevea planting at Bayeux on the northern coast. This grove of a few hundred trees, planted in 1902 or 1903 with seed imported from Singapore, was the subject of a special investigation during 1924 and 1925 by the United States Department of Agriculture. Tapping experiments by Polhamus (*58*) during those years gave average rubber yields equal to those of similar-age trees reported from Southeast Asia. These results, plus rubber-quality studies by the United States National Bureau of Standards, removed any further doubt of the suitability of this or similar districts in Haiti for natural rubber production.

Establishment of Regional Breeding Station

In 1940, with the beginning of the present cooperative program, the isolated western peninsula of Haiti was decided upon as the best location for a regional clone collection and breeding station that should remain free from South American leaf blight. The predominantly northeastern trade winds would prevent air-borne infection from continental areas to the south, and the existing quarantine law on plant importations would protect development of the susceptible but high-yielding Eastern clones and their future use in a breeding program to produce new strains combining resistance with high productivity.

The government of Haiti supplied the United States Department of Agriculture with about 200 acres of land, comprising the old Fort Marfranc reservation, 12.5 miles inland from the city of Jeremie. An office-laboratory and a residence were also provided by that government.

The station was started in 1941, when a valuable shipment of Eastern clones was received from the Philippines. With the arrival of a second shipment of Eastern clones from the Philippines early in 1942, there was established in Haiti material for breeding gardens, clone budwood gardens, and clone comparisons. These shipments of budded stumps of 132 high-yielding clones just cleared the Philippines before Pearl Harbor, and have constituted the basic supply of the best of the Eastern clones needed for rubber development in the Western Hemisphere.

The plantings at Marfranc were started by R. J. Seibert and H. H. Bartlett. Mr. Bartlett had personally escorted the shipment of budded stumps from the Philippines. Seibert remained to direct the station until A. W. Bechtel assumed responsibility for the work in Haiti in March 1942. Bechtel served as director continuously from that time to April 1952. He was then in the United States until February 1954, and during the interim George C. Van den Berghe served as director. Aurel Denizard, an experienced Haitian agronomist, has served continuously as field superintendent since the founding of the station.

During the decade 1942–52, both breeding and seed-production gardens and rubber yield tests of various types, which included more recently blight-resistant clones from Brazil, have been established and now cover 60 acres at the station.

Several of the earlier yield tests have been converted to seed gardens by topbudding with the best Eastern clones and BC_1 hybrids. While some of the BC_1 hybrids are not the best now known, the Marfranc station will soon be producing quantities of seed from the second backcross generation to Eastern clones that should have commercial value in all the leaf-blight-infested countries. As explained earlier, the resistant 50 percent or higher proportion of such seedlings should, after thinning, give average clonal yields comparable to the Eastern parents and require neither basebudding nor topbudding by the small-farm producer.

About 340,000 hybrid clonal seed from Eastern clones were distributed to other cooperating countries in 1952 and 190,000 in 1953. This material will have to be topbudded with resistant clones in districts where leaf blight occurs.

Local Rubber Planting Activity

In 1942, the Societe Haitiano-Americaine de Developpement Agricole (SHADA) Corp., with the aid of a development loan from the Export-Import Bank of Washington, undertook the planting of rubber in four districts of Haiti: Two in the north and two near the western end of the southern peninsula. The corporation supplied its own United States and Haitian managers, and obtained initial multiplication stocks furnished by the director of the Marfranc station and by specialists from Washington. Necessary headquarters buildings and expensive access roads were constructed and maintained in the four districts.

The acreage data given in table 4 were kindly supplied by officers of the corporation. They represent rough estimates only, as detailed surveys had not been made. The area at Francklin (originally cleared as a *Cryptostegia* plantation) has been planted in cooperation with, and as an extension of, the station's experiments.

TABLE 4.—*Land cleared for and approximate acreage planted to hevea in Haiti, 1942*

Plantation	Land cleared for planting	Planted	Present commercial acreage [1]
	Acres	*Acres*	*Acres*
Bayeux-Pioux	2, 200	2, 200	1, 000
Plaisance	1, 026	850	0
Source Chaude	1, 970	1, 870	300
Bourdon	2, 100	250	50
Francklin	------------	104	104
Total	7, 296	5, 274	1, 454

[1] Contains both seedling and budded trees or budded trees only, making a stand of 120 trees per acre.

Recent Commercial Developments

Despite several years' lack of care, plantings listed above as "present commercial acreage" continued to develop and by 1951, when care was renewed, the growth of the trees in these limited areas compared favorably with normally managed plantations of the same age in other countries. Test tapping at Source Chaude in 1949 and 1950 and at Bourdon and Francklin in 1950, conducted under the technical guidance of the Marfranc station, furnished data on tapping costs and rubber yields in Haiti. These data supplied the impetus that led to opening up the trees at Bayeux in 1951. Since that time, the production of rubber on the estates of SHADA has become an important source of revenue. Because of the importance of this planting activity as a practical demonstration of rubber production techniques and economics, personnel of the Marfranc station have maintained a close supervisory relationship to the operations. Visits by W. Mackinnon, plantation management adviser, also were useful in the long-term planning of estate operations. For the southern operations, some 28 tons of smoked sheet rubber were produced in the initial period of May to December 1952 from one-third of the total trees taken into production in that period. In 1953, a total of 100 tons output was estimated. Figure 10 shows a dockside consignment of rubber bales in Port-au-Prince, representing the first commercial export of rubber from Haiti.

In the Bayeux district of the north, 100,000 trees were tapped in 1953, with an annual yield of about 5 pounds per clonal tree. An increase to 8 pounds is anticipated by 1955. In 1954 tappers were producing 5 pounds of rubber per day, and at Bayeux the production was slightly less than 7 pounds per tapper per day. The market price of about 25 U. S. cents per pound left a good margin of profit above all direct and other customarily chargeable costs. The total production of both areas was estimated as 133 long tons in 1953.

The detailed production and cost data have already demonstrated that Haiti could greatly expand its rubber production on a very profitable basis. This has become generally realized. However, such expansion should not be at the sacrifice of food production, as would probably be the case if large areas of the SHADA type were established. Small-farm plantings, especially of rubber interplanted with coffee, offer great promise.

Haiti presents the requisite conditions for combining two cash crops on the same land. These conditions are a dense population (about 250 per square mile), shortage of good land, and need for both an increase in and greater diversification of exports to obtain foreign exchange for increased industrialization of her economy. The situation is similar to that existing in Java, where, over the past several decades, more than 50 percent of rubber exports have come from "permanent" mixed cultures, largely with coffee.

A casual inspection of many of the older coffee plantings in Haiti, which crop contributes more than 50 percent of the country's total exports, reveals the need for more care by the small producer. At present he spends only a few weeks each year in his coffee garden pulling off the entangling vines and picking his small harvest. With rubbertrees supplanting the customary coffee-shade trees (of no value in themselves), he would be in his garden 12 months of the year. Necessary weeding and constant attention, in order to tap the rubbertrees, would indirectly improve the interplanted coffee.

During 1952, the Ministry of Agriculture of Haiti became cognizant of the above potentialities and interested itself in the establishment of new centers for propagation and distribution of planting stock of both

FIGURE 10.—Part of a 7-ton shipment of baled sheet rubber at dockside in Port-au-Prince, Haiti, November 1952.

crops. Coffee is now included at the older rubber center at Chambellan (Grande Anse region), and new centers for both crops are located or planned at Fond des Negres, Petit-Goave, Lesson, and Grande Riviere du Nord.

The demonstration during 1952 of rubber as a promising export product for Haiti, by actual tapping and sales from the scattered earlier plantings, has given great impetus to plans of the government for the small native farmers as well as to larger and independent landowners. According to George C. Van den Berghe, then acting director of the above station, tentative schedules and estimates have been presented for the planting of one million rubbertrees by 1960.

Mexico

Historical

Production of rubber to meet her internal requirements has been a consistent national policy of Mexico since 1940. Prior to this period, Mexico had gone through a complete cycle of rubber plantation development, large exports, followed by decline that may be summarized briefly as follows:

Fear was first expressed over a possible rubber shortage soon after 1870. Up to about 1905, only wild rubber was exploited, but thereafter production from a rapidly expanding plantation industry became dominant. By 1910, the total acreage of rubber plantings was estimated at 136,000 acres, with 9 million trees in the Palenque area alone (*93*). By 1913, activities had become greatly curtailed, because of the low price of rubber and Far Eastern competition. By 1940, most of the plantations had been abandoned or destroyed to make way for other crops. Only a few small areas remained in tapping to supply community needs.

The tragedy of this early industry, as in several other countries, was that the wrong kind of rubbertree had been selected for plantation use. It was natural to choose the native species of *Castilla* that were rapid growers and spectacular in latex flow, although (as learned later) comparatively low yielding and of inferior rubber quality. Had this early surge of interest and heavy investment, including that of many American companies, been devoted to the hevea rubbertree, possibly more of an industry might have survived.

First interest in hevea began in 1908, and later a few scattered plantings, especially at El Palmar and Las Palmas, were started with seed and stumps imported from Southeast Asia. By 1913, when such plantings came into tap, competition with Eastern rubber was keen, and this plus the losses and discouragement from *Castilla* gave little incentive to expand or replant with this new and little-known rubbertree. However, several of the larger hevea plantings continued in production up to 1940, and even in part to the present time.

Cooperative Program

With a rapidly mounting deficit of production under local consumption and with a scarcity of foreign exchange to import rubber, Mexico naturally responded favorably in 1940 to a proffer of cooperation from the United States Department of Agriculture to guide the development of a technically sound industry based on the use of superior yielding strains of the hevea rubbertree.

A joint commission of Mexican and United States technicians inspected various districts, including existing hevea plantings, in the southern States of Veracruz, Tabasco, and Chiapas. The pioneer center El Palmar in the Municipality of Zongalica, State of Veracruz, with some 30,000 mature hevea trees, was selected as the most favorable site for the new development. A memorandum of agreement, signed April 11, 1941, by the Mexican Secretary of Agriculture and the United States Secretary of Agriculture provided that Mexico furnish the necessary land, structures, and materials for a plant multiplication center and the United States furnish valuable planting material and the necessary technicians to cooperate with Mexican scientists toward achievement of the program objectives.

There was developed over the next 3 years, under the able direction of Manuel Gollas A., a modern rubber station, called Campo Agricola Experimental de Hule "El Palmar," with a large permanent office building and residences for the staff. In September 1941, R. E. Stadelman was assigned as United States technician, and in 1943 his services were supplemented by the assignments of W. J. Martin, pathologist, and T. D. Mallery, extension adviser.

At the end of 1943, 2,800,000 rubber seed, collected from the mature trees near the Campo, had been planted for rootstock production and about 53,000 budded stumps of high-yielding clones had been established. Scattered on the 11 "ejidos" (cooperative centers) down the valley from the station, 325 acres of hevea had been planted by 200 individual growers.

In the meantime, continued tapping of the old hevea grove, which also served as a demonstration, had encountered difficulty from a tapping panel infection that killed the bark over large areas. This constituted a serious threat to the future of the new industry. A detailed investigation by Martin revealed this trouble to be a particularly virulent type of moldy rot, long known in Southeast Asia. He developed a tapping-cut treatment, and this with other measures effectively controlled the disease (*51*, *53*). Martin (*51*) also noted and described some 15 other diseases, mostly of minor importance, found in the hevea plantings. A few Eastern clones in multiplication gardens were seriously attacked by alternaria leaf blight, a hitherto undescribed disease of hevea. Martin (*50*), in 1947, published a special report on this disease and its control by spraying.

Of major significance was the discovery in September 1946, for the first time in Mexico, of South American leaf blight. New infections in several nurseries in Chiapas and Tabasco and in October at the El Palmar station, were found to have originated probably from one of the old rubber groves, Finca Hulera de "Santuario," in the Municipality of Pichucalco, Chiapas. That planting of 800 trees had been made in 1910 with small stumped seedlings of unknown origin, but all evidence indicated the disease had been present for many years. This first discovery of the disease north of Costa Rica was described by Martin (*52*) in February 1948 and, more recently, referred to by Puente and Vergara (*61*) of the El Palmar station. A program of nursery spraying and expanded topbudding with resistant strains was quickly inaugurated.

A detailed report on the 1940 field survey, together with progress on the cooperative program through 1944, appeared as a processed publication in June 1946 (*44*). By 1945, about 370 acres of the 740-acre Campo farm were devoted to nurseries and long-term field experiments, the latter to determine the comparative merits of some 27 Eastern clones, best tree spacing, use of intercrops, and other such practical objectives for sound future guidance of an enlarging commercial industry. In May 1944, Ing. Gollas was replaced by Manuel Puente C., who has continued to the present time as chief of Campo, aided by 1 to 3 agronomists and a well-trained labor force.

Even before the departure in 1947 of W. J. Martin, increasing difficulty was experienced in obtaining a fair percentage of budding "takes." Sometimes as low as 3 percent success was obtained. The budpatch on what appeared to be successful takes upon unwrapping, later died. This low budding success was proving to be an enormous wastage of both labor (to repeat the budding) and of budwood and was seriously delaying output of the station for field plantings. In June 1948, A. M. Gorenz, United States pathologist, was assigned to study this problem. He soon discovered that a weakly parasitic fungus (*Diplodia theobromae* (Pat.) Nowell) was attacking the budpatches and causing the budding failures. After trials of many fungicides he recommended (*26*) Fermate, which could be used to disinfect the budwood and base of the seedling stem and was not toxic to the tender cambium of either. Use of this fungicide gave a budding success of 70 to 98 percent compared to only 5 to 45 percent success in buddings where the fungicide was not used. All budders henceforth refused to work without the use of this material, even though they became smeared from head to foot with the black, greasy material, and were given no incentive bonus based on number of takes but worked from pride of achievement.

The station program of annual budded-stump distributions had continued uninterruptedly, but, unfortunately, the followup inspections and advisory work among the hundreds of widely scattered small farms proved inadequate because of the very limited staff of trained agronomists at the station. A young and well-cared-for area with interplanted corn is shown in figure 11.

An unfortunate accentuating factor was the contracting of sugarcane acreage, following completion of the highway from Tezonapa to El Palmar and beyond. Dozens of otherwise successful small rubber plantings were ruined by accidental trash fires that followed harvest of this interplanted crop. Sugarcane did provide much needed cash for the subsistence farmers, and interest in the still immature rubber plantings greatly declined for a few years. Many plots were abandoned and few new ones put out, especially after the 50-percent government subsidy was discontinued. Nevertheless, a considerable number of growers had followed consistently the excellent 7-page mimeographed general instructions on nursery practice and field planting that had been issued and widely distributed by Director Manuel Puente.

In a recent bulletin Puente and Vergara (*61*) have summarized the station program, especially the investigations on budding during the years 1948 and 1949. This constitutes a manual on both basebudding and topbudding of hevea in Mexico. By 1949, many of the earlier hevea plantings contained a sufficient proportion of trees large enough to warrant inauguration of commercial tapping.

In November 1949, the United States Department of Agriculture assigned R. H. Bartlett, a practical rubber planter with experience on the Firestone plantation in Liberia, to conduct tapping schools and assist the station staff in getting rubber production under way.

FIGURE 11.—A 3-year-old small-farm rubber planting with intercultivated corn in El Palmar Valley, Mexico.

By 1952 some 20,000 trees on small farms were reported to be in production with additional areas coming into tap constantly. Most of the production was being purchased as latex by a foam rubber factory in Mexico City. A great resurgence of interest in rubber on the part of both ejidal growers and larger private planters had developed, with demands for planting material exceeding annual output by the station. The station staff, consisting of the principal officials Manuel Puente C., director, Angel Vergara, and Patricio Maldonado P., agronomists, has had to expand both the station program and field extension work. For the extension work 3 full-time planting and tapping inspectors were employed for constant travel to the widely scattered rubber developments throughout the valley. By the close of 1952, it was estimated that some 90,000 trees would be planted and more than 50,000 of previous plantings would be in production.

The most recent (1953) estimate of existing plantings in the El Palmar region, reported by T. D. Mallery, United States technician, is classified under the following groups:

Groups:	*Plantings (hectares)*
Ejidal (135 individual owners)	466
Private (5 owners)	201
Campo (station experiments and plantings)	136
National lands (by government)	136
Old seedling plantings (prior to 1940)	90
Total	1,029 (2,472 acres)

During the month of December 1953, 37,400 pounds of 60-percent creamed latex and 3,828 pounds of blanket-crepe rubber were shipped by the principal buyer from El Palmar to Mexico City. Basic requirements for a successful producing industry have been fulfilled to a surprising extent in the El Palmar region. Because of the pronounced dry season, South American leaf blight on upland sites has not seriously damaged field-grown and untopbudded Eastern clones. Further extension of all-weather roads and encouragement of additional settlers from the overcrowded highlands should permit a large expansion of hevea acreage. Since rubber ordinarily cannot compete with sugarcane on flat, alluvial lands, future rubber planting should be encouraged on the immense areas of rolling hills and not too steep slopes of the several valleys of the region wherever soil of sufficient depth and suitability occurs.

Tabasco-Chiapas Region

The 1940 and subsequent surveys revealed large areas of unoccupied land suitable for the culture of hevea in the foothill zone of the southern mountains of the Tabasco-Chiapas region that is traversed by the Southeastern Railway. The district about the town of Teapa, which is connected with Villahermosa by 35 miles of highway, and the rolling hills extending to Pichucalco, also on the railway, are reported to have excellent potentialities for plantation development. Three colonization centers in the area afforded some labor for larger plantings and at least those colonists who spend part of their time tapping wild castilla might be induced to establish small hevea plantings.

Interest in planting hevea, especially by cacao and banana planters, has existed since the beginning of the program at El Palmar. In 1943 and 1944, 61 planters established seedling nurseries. Only about 10 percent of these nurseries could be budded in 1945 and only 41 percent of the buddings were successful. That left about 420,000 seedlings to be budded in 1946. Difficulties in controlling leaf blight and its deleterious effect on budding handicapped the schedule despite help from the station staff and T. D. Mallery, United States adviser. Seedling trees in several instances were transplanted as shade for cacao. The program then received more adequate financial support and the agronomist Isaac Vidrio was assigned full time to the zone headquarters at Villahermosa. New multiplication nurseries were established there on the State farm. Later, secondary nursery centers were developed near Teapa and Pichucalco. It was estimated that up to 1950, 90,000 trees had been planted in the zone, and that probably 50,000 more trees would be planted through 1953. No recent data on plant survival have been received.

From June 1951 to July 1954, P. C. Conner, United States technician, was assigned to cooperate with Ing. Vidrio in connection with plans for enlargement of the program. By 1953, 2,150 of the older seedling trees on 2 plantations were in tapping, and new nurseries were planted for eventual production of 100,000 budded stumps for distribution.

South American leaf blight, noted since 1946 in most nurseries and field plantings, has proved to be a much more serious factor in the Tabasco-Chiapas zone than in the El Palmar Valley of Veracruz.

Although nurseries of susceptible material must be sprayed regularly with fungicides in both regions, untopbudded Eastern clones in field plantings at El Palmar have not been seriously damaged by this disease. Severe and usually prolonged dry seasons in the El Palmar Valley may be the principal inhibiting factor. In contrast, many similar plantings in the Tabasco-Chiapas zone have remained stunted from repeated defoliation, or at least have not made normal development. Thus, the uniform rainfall distribution, shown in the climatological study by Alfonso Contreras A. (*23*) and by Puenta and Vergara (*61*), which is highly favorable for maximum hevea yields, is also so favorable for the blight that topbudding with resistant clones is an urgent necessity.

Conclusions

From the above, it may be concluded that after 13 years of research and commercial activity, a fairly sound foundation of knowledge and practical experience has been gained and there has been established a substantial beginning of a hevea rubber-producing industry in Mexico. In 1952, around 200 metric tons of rubber were produced. This was less than 2 percent of the 15,523-metric-ton reported consumption. Nevertheless, as new plantings of recent years come into production, the percentage should increase, and, with continued research and consistent government help to meet the increasing demands of small growers for expansion of acreage, rapid future progress is anticipated toward the goal of national self-sufficiency.

Peru

Historical

The Peruvian Government since 1940 has consistently encouraged the planting of rubber as one step in the development of her vast "montaña" (forested Amazonian districts). Following World War II the export price of rubber dropped and the expanded wartime gathering of wild rubber, particularly of the weak types from species other than *Hevea brasiliensis*, has been restricted and the rest subsidized for domestic consumption. Local use in 1950 was reported as about 1,602 long tons, of which 1,548 was local wild rubber and 54 tons imported rubber. By 1952, total purchases were 2,174 tons, but imports were not separately reported.

Subsidization of wild rubber collection has proved a costly expedient, but it has saved foreign exchange otherwise necessary to import Far Eastern rubber and avoided social and economic dislocation by maintaining the rubber tappers as settlers in the lowland areas. The gradual transposition of these people from wild-rubber gatherers to small rubber-farm proprietors, or as laborers on plantations to produce the much cheaper cultivated product, constitutes another incentive for continued government support.

By 1940, the Trans-Andean highway had reached the village of Tingo Maria on the upper Huallaga River, and since then it has been extended to Pucallpa on the Ucayali, which provides deep-water navigation on the Amazon system. A well-organized colonization project was started at Tingo Maria as an initial step toward settling the montaña from the overcrowded coastal areas.

In 1923–24, a rubber survey of the principal river valleys of Peru was made by Schurz, Hargis, Marbut, and Manifold (*83*) as a part of their study of rubber production and areas suitable for plantations in the Amazon Valley as a whole.

Cooperative Program

A memorandum of understanding authorizing a joint rubber survey of Peru was signed August 21, 1940, by the Ministro de Fomento y Obras Publicas of Peru and the Chief of the Bureau of Plant Industry of the United States Department of Agriculture. A survey party, consisting of E. C. Stakman, pathologist, in charge, E. M. Blair, rubber technologist, A. F. Skutch, botanist, and M. M. Striker, soils expert, was joined in Peru by Bernardo Moravsky and M. Sanchez del Aguila of the Peruvian Government.

With information from the earlier survey, this party made no attempt to examine any considerable part of the immense Amazonian drainage region of Peru. The party inspected the lower stretches of the Maranon (as the Amazon is called in Peru) above Iquitos and its principal tributaries, the Napo, Huallaga, and Ucayali. These lower river valleys comprise a vast tropical forest without roads and relatively few trails and with few settlements along the rivers.

Objectives of the new survey were (1) to find where wild rubber might be obtained most economically, (2) to appraise areas most suitable for plantations, and (3) to study the species of *Hevea* in the jungle. Although, in the short period of 3 months, no exhaustive study could be made, much information was accumulated both by direct observation and from testimony of people with long experience in the region. From the still unpublished report, the following places or localities along the above-mentioned rivers appeared to be most promising for rubber plantation development:

Huallaga River.—(1) Tarapoto-Yurimaguas, (2) Sacareto-Navarro-Chipurana, (3) Oromina, and (4) Lagunas.

Maranon River.—(5) Barranca, (6) Aripari, (7) San Lorenzo, and (8) Parinari.

Napo River.—(9) Santa Clotilde and (10) Mazan.

Amazon-Yavari Rivers.—(11) Puca Urquillo, (12) Caballo-Cocha, and (13) Islandia.

Ucayali River.—(14) Requena, (15) Contemana, and (16) Pucallpa.

The climate of eastern Peru in general was considered excellent for the development of rubber plantations. Rainfall, based on scattered records, was reported to be 80 to 110 inches per annum, fairly evenly distributed over the year; temperature and humidity were satisfactory; and windstorms were of insufficient intensity to cause any considerable damage.

Special study was made of several small abandoned rubber plantings: (1) At Oromina below Yurimaguas on the lower Huallaga River, containing about 1,000 trees; (2) Islandia on the Yavari River; (3) Caballo-Cocha; and (4) at Puca Urquillo on the Amazon River. The three latter plantings contained a few hundred trees each. The Oromina planting was said to have been started about 1915 with seed brought from the Acre Territory of Brazil. Tree development had been very irregular. South American leaf blight, black crust, and several undetermined leaf spots and root rots were observed. None was particularly serious in these abandoned semi-jungle areas, all of which are within the general native range of *Hevea brasiliensis* or other *Hevea* species.

The survey party recommended establishment of nurseries at Tingo Maria and at Oromina from which planting material could be multiplied and distributed to planting centers in one or more of the above 16 districts.

Research and Development Program

On November 4, 1940, the Ministro de Fomento y Obras Publicas of Peru and the Chief of the Bureau of Plant Industry, United States Department of Agriculture, signed a cooperative agreement providing for joint investigations and specific steps to start a rubber planting industry.

At Tingo Maria an experiment station, called Estacion Experimental Agricola de Tingo Maria, had been authorized and started in connection with the local colonization project, and here the first rubber nurseries were established. Seed for this purpose was obtained partly from the local jungle species, *Hevea guianensis* var. *lutea*, and partly from shipments made by the United States Department of Agriculture from Panama. Budded stumps were sent from Honduras and Costa Rica. Tingo Maria was planned as the central propagation and experimental nursery for Peru. Small district nurseries, using mostly local seed, were also established at Yurac on the main highway some 100 km. above Pucallpa and, in cooperation with the government laboratory of the Instituto Tecnico Quimico Industrial del Oriente, near Iquitos.

In June 1943, a supplementary memorandum of understanding was signed jointly by the signatories of the above-mentioned previous agreements and by the chairman of the board of directors of the Corporacion Peruana del Amazonas (CPA), the semiofficial Peruvian government corporation charged with rubber procurement. The latter agency was given the responsibility of financing and directing the development of demonstration plantations, with research to continue under the Ministry of Agriculture.

Under the overall direction of such Peruvian leaders as David Dasso, chairman of the Corporacion, and Pedro Recavarren C., director of Experimentation and Colonization of the Oriente, both field plantings and station projects over the next several years were greatly expanded. A further intergovernmental agreement authorized the Office of Foreign Agricultural Relations of the United States Department of Agriculture to assist with the expansion of the Tingo Maria station. United States specialists were assigned as heads of the various departments, with Peruvian scientists as codirectors. In 1943 Rolland C. Lorenz was named chief of the Forestry Department, under which was established the Seccion Jebe (rubber) with Manuel Lescano A. in charge. Lorenz, an experienced rubber technologist, had in 1940–41 served on the Bureau of Plant Industry rubber surveys of Central America and the West Indies. In July 1943, R. J. Seibert, botanist of the above-named Bureau, was assigned to Peru as associate on the rubber project, primarily for jungle exploration and selection work. From 1943 to 1947, he obtained and described more than 300 selections from elite jungle trees—then under wartime exploitation—and from outstanding seedlings in nurseries planted with jungle seed collections.

In December 1943 some 20,000 budded stumps of 7 high-yielding Eastern clones were shipped to Peru from the field station of the Division of Rubber Plant Investigations at Tela, Honduras. In the same year, 18 leaf-blight-resistant clones were shipped from Costa Rica to be tested locally for suitability for topbudding the Eastern clones. During 1945 several additional Eastern clones, not included in the Honduras shipment, were furnished from the field station at Marfranc, Haiti.

By June 1945 the extensive budding programs at Tingo Maria and Yurac had greatly multiplied the Eastern material. Seed for rootstock nurseries had been collected from the highland trees in the jungles near Iberia, Department of Madre de Dios, and about 360,000 seeds had been received from the rubber station in Costa Rica. The Corporacion Peruana del Amazonas had cleared and lined for planting some 305 hectares at its Yurac Plantation No. 1 and some 125 hectares had been planted. At Yurimaguas, a nursery had been started for Plantation No. 2 that would eventually comprise 100 hectares of field planting. Small nurseries were also being maintained at Iquitos and Iberia, while 50 to several hundred budded stumps had been distributed to each of several private cooperators for further stimulation of interest in the rubber project. Budded stumps to plant from 1 to 14 hectares each were requested by 43 additional small farmers, mostly in the colonization project.

South American leaf blight became particularly severe in the Yurimaguas and Iquitos nurseries, and delay in fungicidal control resulted in serious reduction of budding success. On the other hand, at neither Tingo Maria nor Yurac was this disease at all prevalent, according to the annual report for July 1, 1944, to June 30, 1945, by R. C. Lorenz. Leaf blight occurred on the few nursery beds of the local "Jebe debil" (*H. guianensis* var. *lutea*) but not on the adjacent seedlings or clones introduced from Costa Rica that were known to be highly susceptible. Lorenz correctly interpreted this behavior as the result of specialized strains of the fungus, which later, on the basis of regional test plantings in many countries, was confirmed by Langford (*38*).

In 1942 a new leaf disease appeared in the Peruvian nurseries, especially those at Yurac and Tingo Maria. This was first noted by Raymond Russell of the Rubber Development Corp., and specimens were submitted by him and R. C. Lorenz to John A. Stevenson of the Bureau of Plant Industry, who identified it as a *Rhizoctonia* belonging probably to *Pellicularia filamentosa* (Pat.) Rogers. It produces a weftlike mycelium covering the undersurface of affected leaves. In a preliminary report by Lorenz (*48*), it was said to be attacking seriously both leaf-blight-susceptible and -resistant topbudding clones. Only leaf-blight-resistant topbudding clones FB 54 and FB 3363 showed appreciable tolerance.

Because of the threat of this new disease to field-planted trees, a detailed investigation was needed, and J. B. Carpenter, pathologist of the United States Department of Agriculture, was assigned to Tingo

Maria for this purpose. From January 1946 to September 1949, he studied the disease and published several reports (*16*, *17*, *21*, *91*). At first this new disease, named "target leaf spot," appeared primarily in nurseries where it has been readily controlled by the same spray schedule effective against South American leaf blight. However, with the passage of the years, field plantings, especially on the Yurac plantation, topbudded with the series of leaf-blight-resistant clones have been retarded by this target spot. Only FB 3363 showed sufficient resistance to warrant continuance for such use. The prolonged morning fogs during the rainy season in that area were particularly conducive to the spread of this disease. Carpenter tested in nursery beds several hundred blight-resistant clones that were derived originally from the cooperative breeding program with the Instituto Agronomico do Norte at Belem, Brazil. Among all these collections, only a few clones and species showed resistance to target spot. *Hevea rigidifolia* Muell. Arg. appeared to be highly resistant, or immune, and certain clones of *H. benthamiana* and *H. pauciflora* were usually less than 50 percent defoliated. Therefore, since the time of Carpenter, many hybrids between *H. benthamiana* and *H. brasiliensis*, through the courtesy of the Instituto Agronomico do Norte, have been introduced from Brazil for tests of resistance and of suitability for topbudding use. A prolonging and complicating factor is that some clones show high susceptibility to target spot in the nursery but may endure the disease and develop normally under field conditions. Therefore, up to 1953, because of the time required, no final series of approved topbudding clones to supplement FB 3363 had been confirmed for general field use.

Expansion of Field Plantings

During the 5 years 1948–53, about 184 hectares, or 460 acres, of the Yurac plantation has been replanted, and the rest was considered unfit for hevea. The advent of target spot has been a seriously delaying factor, requiring re-topbudding of many Eastern clones having the highly susceptible (to this disease) Ford clone crowns. A large part of the area was originally planted, during 1943 to 1947, with a mixture of untopbudded Ford clones and Eastern clones topbudded with the standard leaf-blight-resistant Ford clones. In common with experience in several other countries, those Ford clones used as panels proved low yielding and are being removed in thinning operations on those parts of the plantation where a good stand of the intermixed Eastern clones was obtained. Unfortunately, only the Eastern clones that were provided with FB 54 and FB 3363 tops show normal development. Therefore, thousands of 3-component trees provided with FB 3363 tops have been necessary to establish Yurac as a successful plantation.

The original selection of Yurac as a plantation site has been much criticized. The soil is highly variable and certain portions, because of poor drainage, probably never should have been planted. High rainfall and morning mists favor diseases. Nevertheless, it is unlikely that any rubber plantation in other parts of the world has been created under ideal conditions. Yurac has presented the problems that sooner or later would be encountered with any large expansion of rubber planting in Peru. Therefore, it may be fortunate that these problems appeared early and could be solved and the lessons learned with no greater loss in time and expense than on the relatively small enterprise at Yurac. In recent years, 1,000 or more trees have been taken into tap and No. 1 standard ribbed smoked sheet rubber has been produced as a demonstration.

The demonstration planting at Yurimaguas consisting of about 67 acres (28 hectares) has been much more successful. This is in a drier climate and no serious trouble has thus far been experienced with target spot, although both it and leaf blight are of common occurrence. Recent reports by W. Mackinnon, plantation management adviser, indicate that sufficient suitable land is available to expand the planting to a more economical unit of 750 acres, or more. Such might not be justified at present, because of its isolation and transportation difficulties, but at some future time it is expected that the northern trans-Andean highway may reach this area. No extensive planting in the very promising Madre de Dios area is recommended at the present time, because of extreme isolation. Several sites for test plantings have been selected in the Neshenya area about 60 km. from Pucallpa.

Since April 1948, H. F. Allard, agriculturist of the United States Department of Agriculture, has been stationed at Tingo Maria to cooperate with Manuel Lescano and the staff of the Rubber Section of the station. Under the aggressive leadership of Ramon Remolina and Joaquin A. Cortez G. of the Corporacion Peruana del Amazonas (now absorbed by the Banco de Fomento Agropecuario del Peru), both research and development projects have been consistently financed and encouraged by the government of Peru. As Cortez long ago correctly predicted, the first 10 years of the program on this new crop has been necessarily experimental, but a sound basis for expansion has now been established.

The unwavering support of the Peruvian Government and the tangible evidence of tree growth and rubber production at the demonstration plantings, including the experimental areas at Tingo Maria, have maintained the confidence of small farmers and colonists in the new crop. In the Tingo Maria area, 12 small farmers had established a total of 83 acres of successful plantings in 1953. During that year, the station received requests for more than 50,000 rubbertree plants. More than half of these trees were to be interplanted with *Robusta* coffee.

Beginning about 1949, Peru has pioneered in the training of young agronomists to serve on her rubber development program. Each year, a small group of senior students from the La Molina Agricultural College at Lima has served a period of 3 months at Tingo Maria to complete their course in tropical agriculture. This has included lectures and practice at the Rubber Section, and each year usually 1 man has been selected and offered a position on the rubber project. Several of these students, after working 1 year at Yurac or other rubber center, have been sent to the central cooperative rubber station at Turrialba, Costa Rica, for further technical training and experience with rubber. As a result, Peru in 1954 probably had more trained agronomists than any other country of tropical America to direct her planned expansion of rubber plantings to meet her rapidly increasing internal requirements.

BASIC OBJECTIVES FOR CONTINUING THE PROGRAM

Southeast Asia supplies more than 90 percent of the natural rubber imports of the Western Hemisphere. For that reason, it has been the consistent national policy of the larger Latin American countries—Brazil, Colombia, Mexico, and Peru—to attain eventual self-sufficiency in this strategic product by expanding their planting programs as rapidly as local finances permit. For the United States, until another source of rubber is available, a stockpile of the Far Eastern product must be maintained.

For the United States

Both strategic and economic objectives for the United States underlie the technical assistance project for rubber production: (1) To obtain indispensable natural rubber during a prolonged emergency that might cut off our Far Eastern source of supply; and (2) to permit eventual reduction of our costly strategic stockpile of Eastern rubber.

If these objectives are to be realized, continued aid will be required for further research and coordination of the widely dispersed developments that now extend from Mexico to Bolivia and Brazil. Such cooperation probably will be advantageous until a minimum total production of 150,000 tons of rubber annually is achieved. This represents merely the minimum annual need of the United States in an emergency, but if production reaches this level, it is likely that the new industry will be able to expand in most countries without further outside guidance.

If, during the next 10 to 15 years, sufficient acreage should be planted to produce this total, it would then probably fall short of meeting the increased internal requirements of the 8 actively cooperating Latin American countries. It must be remembered that 12 to 14 years are required for the rubbertree to reach full production. Therefore, this program, as conducted to date (1954), has not been conceived as an immediate source of peacetime rubber for the United States.

Even without an exportable rubber surplus, no doubt our American neighbors will be willing to exchange a significant part of their natural product for our synthetic rubber to help meet strategic requirements in any future emergency, as they did to a small but vital extent in World War II.

It is the long-period aspect of this program that has made some defense advisers hesitate to endorse United States loans or other financial measures to accelerate production. Now, with the basic research job well advanced to assure a successful industry, such loans or direct capital investments should greatly hasten a rubber-producing industry in the Western Hemisphere.

At present, major reliance in our defense planning has been to stockpile Far Eastern rubber to supply our minimum security requirements. This rubber stockpile is maintained at a stupendous cost, arising from interest on the investment, the usual deterioration of stored rubber, frequent turnover of stocks, storage and handling costs, extra freight, fire insurance, and related costs. Litchfield (*47*) has estimated the annual cost of maintaining a 5-year stockpile at approximately $28,000,000, based on cost of the rubber at 45 cents a pound. This total included $19,000,000 in annual interest on the cash outlay and about $9,000,000 annually for expenses above actual stockpiling. For eventual relief from the cost of such a stockpile, he recommended direct United States investment of about $100,000,000, spread over a 6- to 7-year period, for new plantings of rubbertrees in Latin American countries of approximately 300,000 acres. This investment should also cover the care and development of the trees to tapping age. Such an acreage would constitute a "living" stockpile and ultimately yield 150,000 tons annually. The investment would be self-liquidating, and eventually provide great savings to the taxpayer.

Labor and other major costs of plantation development now are no greater in several of the Latin American countries than in most producing areas of Southeast Asia. Therefore, the suggested contractual enterprises outlined above could be amortized over a period of 25 years according to the usual commercial pattern, and, at that time or earlier, they might be sold to cooperatives organized by the surrounding small farmers. The extent of stockpile substitution achieved from such an investment by the United States would result in a clear and not inconsiderable saving in the present outlay for security in natural rubber.

A detailed plan with cost estimates embodying the above contract proposal was presented during 1951 for consideration by our defense agencies. Its preparation was in response to suggestions in the second report on rubber of the Senate Preparedness Sub-Committee (*94*). Essentially the same proposal was published by the Goodyear Tire and Rubber Co. in its booklet of 1952 (*25*) on "Rubber's Return to the Western Hemisphere." However, with the lessening of the Korean emergency, active government interest in such a long-range project apparently lapsed.

For Latin America

Many Latin Americans remember the wartime rubber shortage and their experience in riding on wornout tire casings stuffed with sawdust. They are determined that it shall not happen again, especially when they can produce the rubber in their own "backyards." In the meantime, internal consumption of rubber has been increasing rapidly in most of the countries.

Latin America, as a whole, has now reached a deficit position in her rubber supply despite subsidization and other temporary incentives to increase costly collection of jungle rubber (1954). Unless a practical rubber program can be devised, this mounting deficit can only be met in the near future by increasing importation of rubber and utilizing therefor millions of dollars of scarce foreign exchange that could better be applied to more essential imports.

However, the cooperative work carried out under the rubber project (1940–54) has provided the technical knowledge and some planting material and has solved many problems for the development of rubber culture. On the basis of the lessons learned, cooperating governments have generally decided that the small-farm planting is the most economical for major production of rubber. First, this must be catalyzed by additional pilot plantations, both government and private, to demonstrate research results and distribute planting material to surrounding farmers, as well as to process their latex (tree milk) like central dairy creameries in the United States.

A series of strategically located plantation units of 1,000 to 2,500 acres each, financed by contract with reliable private companies, after the successful pattern of the Western Hemisphere abaca program, would furnish the bulk of the required rubber tonnage. Additional widely scattered minimum units would give an enormous stimulus to the slowly developing hevea planting program in many of the Latin American countries. Such units would not only serve as pilot demonstrations among those already started or planned, under the limited finance of the countries themselves, but would also provide central plant material distribution centers and later become processing factories. In most districts, the production from the small-farm units would eventually exceed the supply from the initial plantation unit.

This program provides the basis for a living stockpile of rubber for the Western Hemisphere. Moreover, the outlook of the Latin American farmer is changing toward this program. Successful small-farm plantings of rubber are gradually coming into production, and the owners see for themselves the increased daily income for relatively little work. Skepticism for rubber culture is changing to enthusiasm. Several authorities on the subject (*7*, *12*, *33*, *34*, *59*, *63*, *64*, *67*, *100*) have explained in detail the great advantage that the Latin American small-farm producer, with his high-yielding budded trees, has over his counterpart in Southeast Asia, who still depends for the most part upon old, low-yielding seedlings.

Long-term perennial crops, such as rubber, cacao, and oil palm that hold the farmer to a particular area of land, tend to stabilize the population and, through cash sales of more than one perennial crop, to increase gradually the standard of living. Improvement of living standards is one of the main objectives of the technical assistance program for such underdeveloped areas.

SUMMARY

This circular presents a 14-year summary of major activities and results from the cooperative research and development program to establish a rubber-producing industry in 9 Latin-American Republics—Bolivia, Brazil, Colombia, Costa Rica, Dominican Republic, Guatemala, Haiti, Mexico, and Peru. From its beginning in 1940, this program constituted the pioneer foreign technical-assistance project in the field of agriculture. Annual expenditures by the United States and the cooperating countries have varied in a ratio of 1:2 to 1:4, respectively. On July 1, 1954, field projects, personnel, and overall direction were transferred from the Department of Agriculture to the Foreign Operations Administration.

The United States objective is to create a "living" stockpile within our defense zone that may eventually reduce or eliminate our costly strategic stockpile of Far Eastern rubber stored within the country. Latin American objectives are principally (1) self-sufficiency of rubber for internal consumption, and (2) to grow rubber as a cash crop on the undeveloped lowlands by colonists and settlers from the overcrowded highlands.

Economic small-farm or a single-family type of production from 5- to 10-acre plots has been emphasized, although, for effective establishment of this new crop, initial demonstration, or pilot, plantations by government or private companies have been encouraged. These larger plantings also serve as plant-material distribution and latex-processing centers for a surrounding small-farm industry.

The first decade of this program, as anticipated, has necessarily been devoted to the solution of major problems, especially control of South American leaf blight, which hitherto had prevented successful plantation rubber production in the Western Hemisphere. All of the 132 high-yielding strains (clones) of the plantation tree *Heva brasiliensis* imported from Southeast Asia prior to its invasion in World War II proved highly susceptible to this blight.

The participation of the United States Department of Agriculture in the cooperative program has consisted (1) in the establishment and maintenance of regional field stations in Costa Rica, Guatemala, and Haiti, respectively, for basic research, breeding, and disease resistance testing; and (2) assignment of specialists and experienced development advisers to cooperate with local scientists in the remaining countries.

Leaf blight has been controlled economically in nurseries and during the first year in the field by application of modern fungicides and spray techniques. On larger trees, such control would be impractical and uneconomic, but topbudding with resistant clones has been developed commercially.

Fortunately, on the pioneer plantations begun in 1928 by the Ford Motor Co. in Brazil and in 1935 by the Goodyear Rubber Plantations Co. in Panama and Costa Rica, many trees originating from miscellaneous jungle seed collections displayed resistance during devastating leaf blight epidemics. These trees were selected and propagated as clones. In 1943 to 1945, in cooperation with the United States Department of Agriculture, these clones were used to topbud and save the second plantation attempts of the companies (Belterra, in Brazil, and Speedway, in Costa Rica, respectively).

The 3-component tree produced by a double-budding procedure and consisting of an unselected seedling rootstock, a high-yielding trunk, and a blight-resistant crown has become the standard for field planting in all countries where weather conditions favor leaf blight epidemics. The complete tree as a nursery product for distribution to small growers has been developed at the regional station in Costa Rica.

The Ford Motor Co. conducted hevea breeding work on its Brazilian plantations from 1937 to 1946. From 1942, the company shared its breeding material and facilities with the official cooperating agencies, the Instituto Agronomico do Norte at Belem and the United States Department of Agriculture. With the sale in 1946 of the plantations to the Brazilian Government, the latter agencies continued the expanded project. Up to 1954, tapping tests had enabled the selection of more than 2,000 seedlings, resulting from many thousand hand-pollinations made between 1937 and 1943. Only 20 of the seedlings have shown sufficient promise to be included in replicated plot comparisons with topbudded high-yielding Eastern clones.

A better understanding of the 12 recognized species of *Hevea* has been obtained through jungle exploration and taxonomic study, and many elite jungle specimens have been established at experiment stations.

Most promising results of the breeding program in Brazil have been the many interspecific hybrids obtained by crossing the high-yielding but susceptible Eastern clones of *Hevea brasiliensis* with the nearly immune selections of *H. benthamiana* which, though low-yielding, produce a good quality of rubber. Most of the hybrids proved highly resistant but were intermediate in yield. Backcrossing the better hybrids to Eastern clones has resulted in as high as 50 percent leaf-blight-resistant offspring. It is hoped such resistance may be carried to the second and later backcross generations that may provide seed of commercial quality (instead of complicated budded material) for direct planting by small growers.

Through cooperation and courtesy of the Brazilian Government, selections from the costly, long-term breeding program have been furnished all other cooperating countries. These and other selections have been used at regional stations in Guatemala and Haiti, and at the Plant Introduction Garden, Coconut Grove, Fla., to establish (in the absence of leaf blight) special lines of breeding not possible in Brazil.

Some of the *H. benthamiana* hybrids have also proved to be resistant to phytophthora leaf fall, which, since 1950, has seriously damaged plantings topbudded with the blight-resistant pure *H. brasiliensis* selections. These hybrids combine resistance to both diseases with other desirable qualities and are superior for topbudding in most areas.

In cooperative studies at the Department's station at Mayaguez, Puerto Rico, pollination of *Hevea* in nature has been found to be brought about mainly by several species of minute heleid midges.

A great many long-term field experiments have been planted at the regional stations of the United States Department of Agriculture and at those of cooperating governments to determine yield and suitability of new clones, proper tree spacing, temporary cultivation of interplanted food crops, cover crops for soil protection and enrichment, and permanent mixed cropping using hevea to supplant the customary shade trees in plantings of coffee and cacao. Following successful demonstrations in Costa Rica, widespread interest became manifest and extensive mixed plantings of rubber and coffee were made in most of the cooperating countries.

This 14-year summary, to June 1954, provides a resumé of the history and status of the rubber program in each of the 9 actively cooperating countries. Table 1 is presented, showing expenditures for 1953 by the United States and each of the cooperating countries, together with trees in production, and total acreage to date of permanent high-yielding rubber plantings in demonstration areas, by private companies, and by hundreds of individual growers.

The total of about 48,000 acres is a mere beginning toward supplying the countries themselves with this strategic commodity. However, if the breeding program to produce simplified planting material and if essential research are continued, through support and encouragement furnished by Latin American governments and the United States, the present widespread interest by small growers should insure rapid expansion of the rubber crop.

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