SURVEY OF THE NEEDS OF INDUSTRY FOR RAW MATERIALS FROM NEW PLANTS TO BE GROWN IN THE UNITED STATES

H. H. SINEATH
PROJECT DIRECTOR

CONTRACT NO. A-1S-33685
DIVISION OF PLANT EXPLORATION AND INTRODUCTION
BUREAU OF PLANT INDUSTRY
UNITED STATES DEPARTMENT OF AGRICULTURE

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LITERATURE SURVEY

PART I . . . . 1930-45
PART II . . . . . 1952

By

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</tbody>
</table>

This Report Contains 116 Pages
SUMMARY OF PARTS I AND II

This report presents the results of a literature survey to determine the needs of industry in the United States for raw materials from plant sources. The survey covers the periods 1930-45 and 1952 and is the continuation of a similar survey carried out by this group under Contract No. A-1S-33022, covering the period 1946-51. The project was initiated by C. O. Erlanson, Head of the Division of Plant Exploration and Introduction, Bureau of Plant Industry, Soils, and Agricultural Engineering, United States Department of Agriculture.

Periodicals carefully selected for their comprehensive coverage of their particular fields were subjected to a page-by-page scanning, and the published shortages and possible substitutes were recorded. Standard indexes were also examined. The periodicals and indexes were examined for the period January 1, 1930, through December 31, 1945, and January 1, 1952, through November 30, 1952.

The needs and substitutes reported were classified for discussion into the following categories:

1. Fats and Oils
2. Fibers and Wood Products
3. Drugs and Pharmaceuticals
4. Waxes, Gums, and Resins
5. Miscellaneous Materials

During the years previous to World War II only scattered shortages were reported. Most of these were the result of crop failures and seasonal variations in supplies.
The outbreak of World War II caused widespread shortages of many different plant products. Many of the essential oils were virtually unobtainable; drying oils, lubricating oils and edible oils were short. Critical shortages of the following materials also existed: drugs such as belladonna, digitalis, and ergot; hard waxes such as carnauba and candelilla; water-soluble gums such as agar and gum tragacanth; glycerin, alcohols, insecticides such as pyrethrum and rotenone, and tannins.

It is not believed that the further examination of past literature would reveal a significant amount of valuable information.

Throughout 1952 most materials were in fairly good supply. Tung oil and several of the essential oils were short. Peanut oil, castor oil, and coconut oil were reported scarce at scattered times. The botanical drug markets were hampered by shortages of many materials in recent months, but these scarcities are not regarded as critical at the present. The commercial waxes, gums, and resins were in generally good supply, but the search for substitutes for vegetable waxes was stimulated by the high prices of carnauba and other such waxes. Shortages of glycerin and pyrethrum were also reported.

Several possible new raw materials and technological developments were also reported.

Future examination of current literature would probably be of considerable value, especially if the present strained international relations continue.

This report completes a comprehensive literature survey covering industrial raw materials from plant sources for the period 1930-52.
Included in this series of reports are the shortages, possible new raw material sources, and new technological developments reported in the literature published during this period.
PART I

1930--1945
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I. INTRODUCTION

A review of the literature was undertaken as a part of the program initiated at Georgia Institute of Technology by C. O. Erlanson, Head of the Division of Plant Exploration and Introduction, Bureau of Plant Industry, Soils and Agricultural Engineering, United States Department of Agriculture, to determine the recognized or published needs for raw materials from plant sources. A secondary object was to locate published information indicating new crops that might have economic value.

This report, in conjunction with the literature survey report (Phase Report No. 2) submitted under Contract No. A-13-33022, represents a comprehensive literature survey concerning plant raw materials covering the period January 1, 1930, through December 31, 1951.

II. PROCEDURE

The survey of the periodicals was carried out in the following manner. The periodicals examined in the previous survey were re-examined in the light of the information they yielded. Business Week and the Canadian Journal of Research were eliminated because of the insignificant amount of information obtained from them. As the survey progressed, Paint, Oil, and Chemical Review was eliminated on the same basis. Since the Textile Technology Digest was first published in 1944, it was necessary to obtain other periodicals which covered the textile field. After examination of representative issues of leading textile journals, Textile World and Textile Bulletin were selected. The following is a list of the journals examined; the dates for which they were examined are given with each periodical:
(2) American Perfumer and Essential Oil Review (January, 1930--December, 1945).
(4) Chemical Engineering (January, 1930--December, 1945).
(5) Chemical Industries (January, 1930--December, 1945). (Chemical Markets)
(6) Chemurgic Digest (January, 1942--December, 1945).
(7) Drug and Cosmetic Industry (January, 1930--December, 1945). (Drug Markets)
(8) Oil, Paint and Drug Reporter (January, 1930--December, 1945).
(9) Paint, Oil and Chemical Review (January, 1938--December, 1945).
(12) Textile Technology Digest (June, 1944--December, 1945).

Several standard indexes were examined under appropriate headings for the period 1930-45. These were:

The Agricultural Index,
The Industrial Arts Index,
The International Review of Periodicals.
The complex nature of the material desired from the survey necessitated a page-by-page scanning with perusal of those sections or articles which were of interest. The April 21, 1930, issue of the Oil, Paint and Drug Reporter was not available for examination.

III. CLASSIFICATION OF RESULTS

The disclosed needs were classified into these general categories:

A. Fats and Oils
B. Fibers and Wood Products
C. Drugs and Pharmaceuticals
D. Waxes, Gums, and Resins
E. Miscellaneous Materials

Specific items from each of the above classifications that were considered to be of special interest, because of continued shortages or importance to industry, were screened for discussion. Those new materials discussed in detail in the report on the surveys covering the years 1946-51 (Final Report, Contract No. A-1S-33022) are not discussed here except in those cases in which further information has been obtained.
IV. DISCUSSION OF RESULTS

A. Fats and Oils

1. Fixed Oils

The period covered by this survey saw widespread increases in domestic production of many fixed oils. Notable among these were soybean and tung oils. During the 1930's many oil-bearing crops were tested to determine their utility as substitutes for commercially used oils and the possibilities of obtaining them from United States production. Tests were run on perilla, hempseed, lumbang, safflower, sunflower, poppyseed, rapeseed, soya, and walnut oils to determine their suitabilities as linseed oil substitutes (145). Several of these oils showed promise and will be discussed later in this report.

Processed fish oils were used in some paint formulations at various times when other oils were not available or too expensive (192).

The shortages mentioned during the years covered by the survey are presented in Table I. Previous to 1939, most shortages were the result of seasonal influences. With the outbreak of World War II, and the resulting critical shortages of many oils and oil products, the search for new domestic oilcrops was intensified and has generally continued to this time. Critical oils, many of which could be raised domestically, included coconut, palm, linseed, castor, tung, olive, babassu, oiticica, rapeseed, cottonseed, perilla, and palm kernel. (98) Many other oils were tested, especially those which might provide substitutes for some of the drying oils.

During the war, also, increased development of oil and fat production in Latin America took place. Mexico was producing castor beans,
<table>
<thead>
<tr>
<th>Oil or Source</th>
<th>1930-35</th>
<th>1936-37</th>
<th>1938-39</th>
<th>1940-41</th>
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<tr>
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<tr>
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<td>Soybean Oil</td>
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<td>Sperm Oil</td>
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<td>Tea-Seed Oil</td>
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</tbody>
</table>
cacahuananche oil, and a substitute for coconut oil from coyol nuts; Brazil produced castor beans, babassu nuts, oiticica oil, cashew oil, tomato-seed oil, and a substitute for coconut oil from the palm Cocos coronata; Argentina and Chile increased olive oil production. (59, 77)

a. Drying Oils

(1) Castor Oil (Dehydrated). During the later years of the period covered by the survey, dehydrated castor oil gained favor as a drying oil, especially as a substitute for tung oil (26).

(2) Flaxseed and Linseed Oil. Linseed oil is the most widely used of the drying oils. A treatment of linseed oil has been described which introduces conjugated double bonds instead of isolated double bonds in the molecule. It was stated that the oil then resembles tung oil in many respects. (151)

Because of serious shortages of food oils during World War II, linseed oil was used as a shortening after hydrogenation (71).

Several oils were considered as substitutes for linseed oil in paint formulations. The seeds of the candlenut tree (Aleurites moluccana) yield 58 to 60 per cent drying oil which is said to be a satisfactory substitute for linseed oil. The cold-pressed oil is almost colorless after filtration, but extraction with hot petroleum ether gives a brown oil with an unpleasant odor. (72) Rubberseed also yields an oil which can be used as a substitute for linseed oil. This might be a profitable byproduct of the rubber industry. One ton of the light yellow oil can be made from 500,000 to 1,000,000 seeds (each tree produces 400-800 seeds). The oil corresponds with a second quality linseed oil; however, rubber planters are not anxious to see the seed gathered since it acts as a natural fertilizer. (195)
(3) Oiticica Oil. Oiticica oil itself first began to assume some importance in the 1930's. It was first introduced as a substitute for tung oil and has largely continued in that position up to the present time. (203, 233)

(4) Soybean Oil. In addition to its widespread use as a source of drying and semidrying oils, the soybean has yielded other valuable products. Soybean milk, made from dried soybeans, is caused to form a curd similar to cottage cheese and which can be used in many food preparations (130). By parboiling the beans in a sodium bicarbonate solution and then puffing them and removing part of the vegetable oils, a tasty nutlike confection can be made (140). Soybeans have been finding wider and wider applications in the diet of diabetics, as their high food value and unique composition make them peculiarly adapted to this type of diet (152, 227). Fibers resembling wool have also been made from soybean protein (168). Other possible uses of soybeans and oil are in making foundry cores (95), as an antiknock agent in gasoline (199), and in a rubber substitute (116).

(5) Tung Oil. The first plantings of tung trees in this country were made in Florida about 1905. Commercial production of the oil did not start until some years later; during the 1930's and World War II domestic production increased enormously, but not enough to supply the needs of this country. Consequently, during the war, when supplies of Chinese tung oil were cut off, critical shortages developed and searches were made for new drying oils. (183, 184, 258)

(6) New Drying Oils. Many possible substitutes for the various drying oils have been mentioned. Several synthetic oils were
developed (10, 30, 82, 101). Many domestic oils have been considered as drying oil substitutes. Oils have been extracted from elderberry seeds, huckleberry, and other plants. Elderberry-seed oil compared favorably with linseed oil in certain qualities, especially in drying time. (161, 162)

Those oils mentioned as substitutes during the period covered by this survey but which have been discussed in Appendix I, Final Report, Contract No. A-1S-33022, are not discussed further here. These oils are Garcia nutans, grapeseed, milkweed-seed, safflower, and sunflower.

(6.1) Anda-assu Oil. This oil, which is a very promising drying oil, is obtained from the seeds of Joannesia princeps, a plant which flourishes in Brazil, especially in the state of Espirito Santo. The yield of oil is 22 per cent, the iodine number is 142, and the acid index is 0.30. (9)

(6.2) Bagilumbang Oil. The bagilumbang tree (Aleurites trisperma) was introduced from the Philippine Islands and was reported to yield an oil which rivals tung as a drying oil. It grows well on both limy and acid soils and can probably be grown in the warmer parts of the Gulf states. The tree can be propagated either from seeds or from cuttings and grows rapidly, reaching a height of 45 feet. The fruit, from two to three inches in diameter, usually has three cells, each of which contains a single seed or nut. Like tung kernels, these nuts can be separated easily. (16)

(6.3) Kukui Oil. A drying oil practically identical to tung oil and usable for the same purposes is derived from the Hawaiian kukui tree (Aleurites moluccana). The tree yields more oil
than tung but the trees are widely scattered. The nuts are covered by a thick hard shell. (58)

(6.4) Po-Yok Tree Oil. The oil from the kernels of the po-yok tree (*Afrolicania elaeosperma*), native to tropical West Africa, is very closely related to oiticica. Paints made from po-yok oil are not equal to those made from tung but are generally superior to those made from linseed oil. (142)

(6.5) Walnut Oil. The kernels of the Iguape walnut yield 60 per cent of a greenish-yellow oil which, after heat treatment for four hours at 280°F., forms a more desirable paint vehicle than linseed oil. Further treatment yields a quick-drying varnish base. (153)

b. Other Oils. Substitutes for many of the commercial oils other than drying oils were necessary during World War II. Possible new sources of oils are several South African plants, which may yield edible oils (129); avocado oil is a possible substitute for olive oil (79); certain Brazilian palms have yielded edible oils (239, 240); and coffee beans have given an oil which can be used as a motor fuel (34).

(1) Babassu Oil. Babassu oil, the most important of the New World palm oils, is obtained from the babassu palms *Orbignya martiana* and *O. oleifera*, which are native to Brazil. From two to eight enormous clusters of fruit are produced, each weighing around 200 pounds and containing from 200 to 600 fruits. The outer portion of the fruit is a dense, tough, fibrous husk. This surrounds a thin, mealy mesocarp and the nut, which has a thick exceedingly hard shell. Development of the industry was retarded until machines were available to crack the nuts. The nuts contain from two to six kernels with a 63 to 70 per cent
oil content. Babassu oil is expressed from the kernels and, when refined, is used as a substitute for coconut oil in the margarine, baking, confectionary, and soap industries. It is superior to cottonseed oil as a light lubricant (it does not attack bronze) and is almost as good as petroleum for Diesel fuels. The shell yields acetic acid, coke, and tar. (1; 209, p. 203)

(2) Coconut Oil. It was found that the crude residue from coconut oil manufacture can be processed to yield a wax melting at 93°-96° C and suitable for floor wax, furniture polish, and leather polish (259).

Many substitutes for coconut oil were tested. Several companies made special blends of fatty acids having physical constants approaching those of coconut oil fatty acids (190). Sulfonated oils were replacements for coconut and palm kernel oils in some uses (33). Other substitutes for coconut oil have already been mentioned.

A source of odorless coconut oil was found. The oil does not have the characteristic smell of the usual grades of edible oil. This property also makes it useful in cosmetics. (191)

(3) Cottonseed Oil. By special processing, cottonseed oil can be converted into a substitute for cocoa butter. The physical differences between the two are minor. The substitute has a slightly longer plastic range, supercools less strongly, and contracts slightly less when solidified. (32)

Cottonseed oil exports from Brazil were restricted during World War II to force its use as a Diesel fuel there (19).
(4) Olive Oil. Several olive oil substitutes have been mentioned. The oils extracted from the Macauba nut of Brazil have been found to be excellent for alimentary and industrial purposes, one type being identical with olive oil. The nut contains about 65 per cent oil. (238) The kernel oils of Bactris setosa and Astrocaryum vulgare, also Brazilian plants, are of excellent quality and rival olive oil for cooking and for other edible uses (148). Other possible olive oil substitutes are tea-seed oil, rapeseed oil, lard oil, nonoxidizing mineral oil, peanut oil, castor oil, pine oil, saponified red oil, peach-kernel oil, and also many synthetics (103, 105, 124).

(5) Oyster-Nut Oil. The oil is expressed from the kernels of oyster nuts (Telfainea pedata), which are indigenous to East Africa and grow rather widely in Tanganyika territory. The yield of oil from the kernel is 62 per cent. It is said to be usable in cosmetic formulations. (100)

(6) Peanut Oil. The use of peanut oil as a possible olive oil substitute has already been mentioned (105). A simple process to decolorize red peanut skins has been developed. Protein made from the nut meal is suitable for spinning fiber and for making cold glue, paper coatings, and cold water paints. (121) A variety of feed yeast has been obtained from the waste liquor of peanut meal processing. Fermentation of this liquor yields a protein feed product valuable for its vitamin content. (50)

(7) Pine Oil. A new process for the synthetic production of pine oil from gum turpentine was developed in order to meet wartime needs (138).
(8) **Rapeseed Oil.** Fanweed (*Thlaspi arvense*) seeds contain 30 to 40 per cent oil of a composition similar to that of rapeseed oil. The viscosity and the change of viscosity with temperature are similar to those of rapeseed oil. This suggests that fanweed-seed oil could be used in place of rapeseed oil as a lubricant constituent and for other industrial purposes. The plant grows abundantly in the Northwest and North Central United States and in southwestern Canada. The yield from irrigated plantings grown in Montana was found to be about 1,500 pounds of seed per acre. (181, 182)

A product called phytosterol has been successfully extracted on a small scale from a byproduct of the sulfate wood pulp industry. It is claimed to be of special value in the manufacture of marine lubricants, cosmetics, medicinal salves, and oleomargarine. On the whole the product may be used as a substitute for wool fat and rapeseed oil. The raw materials from which phytosterol may be extracted are not confined to the byproduct mentioned above but are also obtainable in the soya bean industry and several of the grain oil industries. (80)

(9) **Tomato-Seed Oil.** Tomato seed yields an oil similar to cottonseed, soybean, and sesame oils. By continuous extraction with ether or carbon disulfide a 22 per cent yield of crude oil may be obtained. After processing with caustic soda, bleaching, and deodorizing, the refined oil is an agreeable, nutlike, bland product. It contains 45 per cent olein and 34.2 per cent linolein and should hydrogenate well. The meal left after processing may be used as a cattle food. (97, 256).
2. Essential Oils

Supply conditions of the essential oils during the period 1930-45 were affected mostly by the international conditions which prevailed during the period. A list of the essential oils mentioned as short and the times during which they were so mentioned are given in Table II. Only scattered shortages were mentioned during the first six years of the period; most of these were the result of seasonal and climatic conditions. In the years of 1936 and 1937 the outbreak of the Spanish Civil War and the Japanese invasion of China caused shortages of certain oils imported from these regions. Again at the outbreak of World War II and in the subsequent years widespread shortages occurred. Many of these resulted from the lack of shipping space from the producing areas and were not due to a decrease in production during the war.

At the beginning of World War II there was widespread interest evinced in the possibilities of domestic production of many of the critically short essential oils.

When scarcities began to become serious, various substitutes for the essential oils were tried. Synthetic aromatics were used at first with whatever was available of the natural products. Little by little they replaced the natural products entirely because there was no possible chance of obtaining additional natural materials. Many of the substitutes also became scarce, which stimulated the search for further substitutes and attempts at domestic production. (217)

In 1940 the oils obtained domestically were oil of turpentine, oil of sassafras, oil of wintergreen, sweet birch oil, witch hazel, erigeron oil, oil of pennyroyal, oil of peppermint, oil of spearmint, oil of tansy,
### TABLE II

**SHORTAGES OF ESSENTIAL OILS, 1930-45**

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<th>Oil</th>
<th>1930-35</th>
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<th>1940-41</th>
<th>1942-45</th>
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oil of wormwood, oil of wormseed, chenopodium oil, apricot oil, oil of bitter almond, cedarwood oil, and hop oil. (45) During the next few years the oils investigated for possible domestic production included geranium, vetiver, valerian, calamus, coriander, parsley, celery, lavender, caraway (45), fennel (254), rose, cherry laurel (255), clary sage, dill weed (217), lemon-grass (250), anise, thyme (196), and tarragon (218). Most of these were not successful as commercial crops although they could be grown in this country. The cost of production was so great as to make impractical commercial-scale production in peacetime (236).

The production of many oils in Central and South America was increased or, in some cases, started. However, the lack of shipping space limited their usefulness. (59, 165, 217)

a. Almond Oil (Sweet). Walnut oil has been mentioned as a substitute for sweet almond oil. The samples mentioned are somewhat lighter in color, pleasant in odor, of similar viscosity, and of nice feel. Avocado oil is also mentioned as a substitute for sweet almond oil. (14, 156)

b. Angelica Oil. The yield of oil from domestically cultivated angelica is almost the same as that obtained from the best imported saxonian type and is higher than that from domestic wild species. The flavors of the imported and domestically cultivated are similar; the index of refraction of the former is lower and the acidity higher. (108)

c. Oil of Anise. It has been found that anise can be grown successfully in Idaho and Oregon. (141)

The oil of Myrrhis odorata has been mentioned as a substitute for oil of anise. Its anethol content is 80-85 per cent (80-90 per cent for
anise); it is similar to anise in refractive index, specific gravity, color, odor, taste, and solubility. Its economic feasibility was not discussed, nor its habitat. (110)

d. **Oil of Bergamot.** The Italian suppliers of bergamot were completely cut off from our markets during the war, and bergamot produced in Brazil was not of sufficiently high quality to satisfy American consumers (250). Several synthetics were developed, one of which was said to be so satisfactory that it was predicted that many users would never return to using the natural oil (cf. Phase Report No. 2, Contract No. A-1S-33022, pp. 18-19). (197)

A new oil which could yield a substitute for bergamot oil has been produced in Mexico from *Lima chichona* (*Citrus aurantifolia*). A ton of the raw material yields about five pounds of oil. Only small plantings of the tree had been made, and no immediate increase was anticipated. (93)

e. **Oil of Camphor.** During the war it was found that camphor trees could be grown successfully along the southern Atlantic seaboard and in the midportions of California, Oregon, and Washington. However, no prospects of commercial production were mentioned. (150)

Several synthetic substitutes were developed, one of which used turpentine as a starting material. (131, 194)

Among the plants noted as yielding substitutes for camphor was *Ocimum canum*, a perennial of the mint family and native to East Africa. It can, however, be grown successfully in this country. The plant does not suffer from any known disease, herbivorous animals refuse to eat it, and, while frost will kill the stalk, moderate cold will not kill the entire plant. It yields upon distillation a goodly percentage of essential
oil and camphor. Planting and cultivation are simple. The yield from
the African-grown plant has been estimated at about 200 pounds of cam-
phor and 200 pounds of oil per acre. Analysis of material produced in
East Africa has shown that the camphor has the same chemical and physi-
cal properties as Japanese camphor. Experimental cultivation in the
United States has yielded camphor which meets United States Pharmacopoeia
requirements but has a slightly different odor from Japanese camphor.
Further experiments have borne out the data obtained from the East
African material. (261, 262)

g. Oil of Eucalyptus. Eucalyptus has been grown in Florida
and California but only for the lumber, not for the oil. (150)

The essential oil of *Eucalyptus globulus*, from the forests of
LaPlata, has been found to compare favorably with the oil of *Eucalyptus
australiana*. Its eucalyptol content is about 76-78 per cent as com-
pared to the Australian variety’s 70 per cent. The oil mentioned is
from the foliage, that from the flowers having a eucalyptol content of
about 46 per cent. (109)
h. Oil of Lavender. It has been found that there is twice as much essential oil in the flowers of domestic lavender as there is in the imported. The indexes of refraction are the same and the flowers are similar. (108)

Oil of cedarleaf was mentioned as a possible replacement for oil of lavender in tincture of green soap. (202)

i. Oil of Lemon-grass. In 1934 tests were begun to determine whether lemon-grass (Cymbopogon citratus) would be suitable for a commercial crop in Florida. Pilot plant studies were begun in 1937. As a result of these studies commercial production was begun, based on the sale of the oil and the sale, as a byproduct, of the press cake as a cattle food. (178) About 1,000 acres were soon in production, and it was expected that these would supply about 100,000 pounds of oil annually. Samples of the oil showed it to be about 75-80 per cent pure citral. (69)

j. Rose Oil. A very fine grade of rose oil (Rosa centifolia) of quality comparing favorably with European oil has been obtained from plants grown experimentally in East Texas. The odor is different from that of European products. (255)

k. Oil of Sage. Sage has been grown successfully in certain regions of this country, mainly Idaho and Oregon (141). However, sage requires two years' growth before the first harvest, and a good bit of work must be done by hand. (141)

l. Oil of Vetiver. Vetiver has been grown successfully in the lower southern strip of the United States. Plantations were under cultivation before the entrance of this country into World War II. (225)
m. New Essential Oil Sources. In Australia there are many small trees and shrubs known as "tea trees" whose leaves and end branches contain essential oils easily obtainable by steam distillation. One of these, Melaleuca linariifolia, which is commercially exploited in Queensland, contains a pale, lemon-colored essential oil with a nutmeg odor useful in soaps and perfumes.

Along the North Coast district of New South Wales the tree Melaleuca alternifolia contains an essential oil similar to the above and which can be removed by steam distillation. The oil is used in crude form in medicine and therapeutics, and the standardized oil is used in surgical work. The supply of raw material is almost inexhaustible because new shoots and branches grow from the stumps. (13)

Oils extracted by steam distillation from Douglas fir and Ponderosa pine needles were found to be useful in scenting soaps and other toilet articles. Laboratory tests showed that western red cedar oil has useful insecticide properties; it was tested on chicken mites successfully. (212)

B. Fibers and Wood Products

Nearly all of the commercially used fibers were short during World War II. Notable among these were the hard fibers, especially Manila hemp. There were also widespread shortages of cotton and wool products, brush bristles, cork, kapok, pulpwood, and other wood products. These shortages were the result of greatly increased demand and the loss of foreign sources of supply.

1. Bristles

The outbreak of World War II cut off China as a source of supply of hog bristles for paint and other types of brushes, and this material
was soon critically short. It was found that horsehair could be used for certain types of brushes, but this hair showed very poor water resistance (21, 200). Paint brush bristles of a fairly good quality were made from casein; brushes made from these had good paint-carrying capacity, made smooth films, and had good wear resistance. They were resistant to oils and fat solvents but softened in water. (83)

2. Cork

Since cork is imported mainly from the Mediterranean region, the breakdown of trade during World War II caused scarcities of the material. This effect was further strengthened by the large increase in consumption of cork for military uses.

It was found that some cork oaks were growing in the United States in California and throughout the South. Attempts were made to encourage the planting of the tree, but immediate results could not be expected since 30 years of growth are required before cork of commercial value is produced. The tree has been planted in many places as a shade tree, and it is hoped that sufficient plantings of this type may be made to insure a good domestic supply at some time in the future. (36; 185; 209, p. 83)

Many possible substitutes for cork were mentioned. It was found that peanut hulls could be processed into a cork substitute by grinding them into a fine meal and then milling the meal with liquid. This formed a product which could supplement cork in wallboard, inner soles, bottle caps, and many other articles. (84, 118, 119, 222) In Germany, potato peelings were processed to yield a cork substitute (42). The roots of the Jamaican "cow apple" (Annona palustris) yield a corklike material suitable for corking vinegar or similar liquid products (132).
A tree called "Florida Velvet" and growing in southern Florida, especially in the Everglades, has wood which is ten times lighter than cork and which retains its buoyancy after weeks of immersion in water (49).

3. Hard Fibers

The three main cordage fibers, abaca, sisal, and henequen, were all critically short during World War II. The search for substitutes for these extremely important materials has continued to this time. Some of the possible substitutes have already been mentioned in a previous report (Appendix III, Final Report, Contract No. A-1S-33022) and will not be discussed further here.

a. Abaca (Manila Hemp). With the major source of supply, the Philippine Islands, no longer available as a supplier during World War II, attempts were made to develop the production of abaca in the tropical regions of this hemisphere. Successful plantings were made in Costa Rica, Guatemala, Honduras, and Ecuador. The production in these regions was quite small, however. (123, 198)

While many other plants suitable for cordage already grew in this hemisphere, not many had been commercially utilized. The increased demand for fibers during the war caused re-examination of the possibilities of many of the plants.

b. Caroa. Caroa (Neoglaziovia variegata) is found in large quantities in most of the northern states of Brazil. The leaves are mechanically decorticated and yield a soft, white, flexible, elastic fiber three times as strong as jute. Caroa can be used as a substitute for jute and in the manufacturing of rope, string, tarpaulins, carpets, and paper. It has also been blended with cotton for the manufacture of
fabrics. Bags made from caroa are lighter, more resistant to abrasion, and of better appearance than those made from jute. (209, p. 411; 237)

c. Fique. Fique, from Furcraea macrophylla, is a fiber closely resembling sisal and is grown to a small extent in Colombia. During World War II, when sisal was unavailable, coffee plantation operators used fique for bags. Since most of the fiber has been taken from wild-growing plants, it is not known how far the fiber yield could be raised above the two per cent obtained from these plants if scientific methods of growth and harvesting were used. The fiber is reported to be fine and lustrous, comparing well with sisal and Mexican henequen. (70)

d. Guaxima roxa. This plant, (Urena lobata), also known as "Aramanica," yields a fiber usable for the manufacture of rope, twine, and sacking. The fibers are more than a yard long, flexible, strong, nearly white, and silky when dry. The tensile strength of the fiber is claimed to be greater than that of jute. The plant thrives best in the damp soil of the Brazilian coastal region, although it grows throughout the nation. (118)

e. Yuccas. Several species of the genus Yucca have been investigated as possible sources of hard fibers. These plants grow in the southwestern United States throughout Arizona and New Mexico.

(1) Yucca glauca. This species grows in East Central New Mexico and produces a high percentage of fiber when dry. The yields are about 375 pounds per acre. (176, 177)

(2) Yucca elata. This species is widely distributed over the central and southern plains of New Mexico. The leaves contain 1/3 per cent fiber when dry, and the yields amount to about 450 pounds of fiber per acre. (176, 177)
(3) *Nolina microcarpa.* Nolina grows in both Arizona and New Mexico in sandy, gravelly hills and plains. The dry leaves contain 48 per cent fiber, and yields are estimated at 500 pounds per acre. (176, 177)

These species of *Yucca* and *Nolina* are similar in properties to sisal, although *Nolina* is somewhat weaker than jute. These are believed to be suitable material for making cordage and bagging. The fiber is not suitable for marine use. A machine for extracting the fibers of yuccas from the leaves was developed. (46, 169, 170, 176, 177)

f. Other Hard Fibers. Also mentioned as sources of hard fibers were *Piassava* (*Attalea funifera*), *Maguey*, *Tucum*, *Istle*, *Mauritius hemp*, coir, pineapple, *malva*, cabaya, canamo, pine-needle fiber, and Cuban hemp. (47, 251)

4. Kapok

Because of its buoyancy and resistance to water, kapok was in great demand during World War II as a filling material for life preservers, life cushions, portable pontoons, and similar articles. The United States normally imports large quantities of kapok, chiefly from Java, the Philippines, and Ceylon, and some from Mexico. During the war, when most of these sources of supply were no longer available, substitutes had to be found. There were two substitutes which were widely used.

a. Cattail Fluff. Fibers attached to the seeds in the swamp cattail (*Typha latifolia* and *Typha angustifolia*) found many industrial uses because of their remarkable characteristics of buoyancy, thermal insulation, and sound insulation. The fibers are less than one-half inch long and are tubes composed of a number of compartments in which the air is trapped. (27, 159, 204)
b. Milkweed Floss. Several of the milkweeds are used as sources of stuffing materials. In the United States *Asclepias syriaca* and *A. incarnata* produce the best and most abundant floss. Milkweed floss is just as buoyant as kapok and is an excellent insulator. It was widely exploited during the war as a kapok substitute. (74; 209, p. 49; 257)

5. Soft Fibers

a. Flax. Previous to World War II only very small amounts of fiber flax were grown in this country. Oregon and Michigan were the only states which consistently grew flax from 1930 until the outbreak of the war; at that time production was increased. Ten new processing plants were built in Oregon during that period. The processing facilities of Oregon require about 15 to 20 thousand acres of flax annually to maintain efficient operation. It was also mentioned that flax could be grown on uneconomic cotton land. (228, 243)

b. Hemp. Hemp, once an important American fiber crop, was in extremely small domestic production at the beginning of World War II. The United States Department of Agriculture at that time began a program to encourage the domestic production of hemp. This program was very successful as far as the war effort was concerned. (60, 125)

c. Jute. Since virtually the only source of supply of jute is India, supplies of this material were critical during the war because of shipping difficulties. Many fibers were tried as possible substitutes for jute, and other soft fibers have been discussed in a former report (Final Report, Contract No. A-1S-33022). Three of the most important of these are ramie, roselle, and kenaf. Others are discussed in the following sections.
d. Brazilian Hemp. Brazilian hemp, or papoula de Sao Francisco (Hibiscus ferax, H. radiata, H. unidens), grows in Bahia and Minas Geraes. Plantations have been started in Sao Paulo. The fibers are uniform, yellowish in color, and are used to a small extent in the manufacture of strings, rope, cord, and sacking. Its seeds produce a drying oil which can be used in paint and varnish. (237)

e. Bromelia karatas. This plant, also known as Bromelia de Colombia, is said by some to be better than ramie as far as durability is concerned. It grows in Central and South America and was used for fiber many years ago. Millions of acres are growing wild, but no one as yet has been able to develop an economical method of processing the fiber. (229)

f. Okra. Okra possesses a fiber of the Manila hemp, or sisal, class. It has been proved a suitable substitute for sisal although its tensile strength is somewhat less than that of sisal. Other characteristics are comparable to those of Manila hemp. (268)

g. Urena lobata. This is a perennial, bushy plant which grows wild in Florida. Two cuttings per year can be made after the first year. The fibers are long, light-colored, and silky. It has been cultivated commercially in the Belgian Congo and in many Central and South American countries. (268)

6. Wood and Wood Products

Because of the vast increase in the consumption of wood products, especially paper pulp, during World War II, many of these products were among those critically short during the war.
a. Fiberboards. Several new materials for making fiberboards were mentioned. One ton of sawdust will yield 2,000 square feet of high-quality wallboard. Fiberboards can also be made from chips, shavings, and bagasse. (155)

b. Paper Pulp. Some sources of paper pulp were discussed in a previous report (Final Report, Contract No. A-15-33022). Bagasse and bamboo seemed to be especially valuable as sources of newsprint. Other usable wood pulp sources are corn stalks and leaves (for medium grades of printing paper, wrapping paper, parchmentized paper, and cardboard) (193), flax (for fine light-weight papers) (48), wood waste (102), and prunings from apple, pear, peach, plum, cherry, orange, and lemon trees (188).

A war development which probably contributed to the shortage of wood pulp was a new process for manufacturing smokeless powder using wood pulp as a base. The process permits the use of lower grades of wood for pulp than are usually used for paper-making purposes. (87)

c. Wood Waste Utilization. The production of alcohol from wood waste has been mentioned. The conversion of lignin into a thermosetting composition useful as a wallboard in the same process should permit economical alcohol production by this method. (253)

A great many industrial uses for corncobs have been proposed, and it seems that the great barrier to greater utilization is the lack of favorable economic conditions rather than the lack of knowledge of products and processes. Some uses mentioned are as heat insulation, in lightweight ceramics and tile, as a filler for plastics, a substitute for granulated cork, and an absorbent in the manufacture of dynamite. (61)

Plastics have been made from bagasse, sawdust, and cotton (38, 114, 174).
7. Synthetic Fibers

Several synthetic fibers were developed during the period covered by this survey. The war was an effective catalyst to research in this field. Nylon was put into commercial production just before the war, and was widely used for military purposes during the war years.

"Ardil," a woollike fiber from peanut protein, was developed and put into commercial production by a British firm. Its main use was expected to be in blends. A similar fiber from peanut protein was developed in this country. (104, 265) Soybean protein and corn protein have also yielded fibers similar to wool which were put into commercial production. (137, 224)

Other synthetic fibers which may be of some importance were obtained from seaweed (44), redwood bark (17, 246), and fish meal (136). A fabric of leatherlike properties which could serve as sole material for certain types of shoes was made from cotton (39).

C. Drugs and Pharmaceuticals

Supplies of drugs and botanical drug sources were, in most cases, adequate until the outbreak of World War II, when the loss of many foreign sources of supply caused shortages of many important drugs. Many of those drugs normally obtained from domestic collection of botanicals were short because of small collections during the war years. Those workers who usually collected herbs found that other jobs were more remunerative. The shortages of drugs and pharmaceuticals in the years covered by the survey are listed in Table III. Shortages immediately after the beginning of the war were not serious because of the fairly large stockpiles that were available (210). Increases in domestic
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<th>Item</th>
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TABLE III (Continued)

SHORTAGES OF DRUGS AND PHARMACEUTICALS, 1930-45

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### SHORTAGES OF DRUGS AND PHARMACEUTICALS, 1930-45

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<tr>
<td>Tamarinds</td>
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<tr>
<td>Uva Ursi</td>
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<tr>
<td>White Pine Bark</td>
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<tr>
<td>Wild Cherry Bark</td>
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</table>
production of some materials averted serious shortages in several cases. Among the drug plants which were grown commercially in this country during the war were belladonna (220), arnica (211), digitalis, ephedra, senna (18), stramonium, and henbane (127). (218) Ergot was obtained to some extent from rye grown in this country (7).

Almost any botanical can be grown in the United States as far as conditions of growth are concerned. The main problem has always been that many drugs cannot be grown here economically when foreign sources of supply are available. The drug sources can be divided into several groups: (1) Those essential to the formulae of manufacturers and for which those manufacturers are willing to contract for cultivation. (Drug sources such as arnica flowers, larkspur, chamomile, and dandelion fall into this category.) (2) Those vital to the health of the nation which must be produced regardless of cost or normal competition. (Belladonna, digitalis, hyoscyamus, and stramonium are examples of these.) (3) Those which have long-range possibilities as permanent domestic crops, i.e., drugs which can be so greatly improved in quality and yield as to compete with lower-quality materials offered from foreign sources. (226) During World War II studies were made on a great variety of botanicals for drugs and substitutes. Besides these plants already mentioned as being grown commercially in the United States, other plants were used in varying degrees.

1. Digitalis

A substance called cedilanid, found only in Digitalis lanata, a Balkan variety of foxglove, has proved more effective than the digitalis in common use for treating heart disease. It has the same effect as digitalis and acts more rapidly. (41)
2. Menthol

During World War II American peppermint was used as a source of menthol. Large quantities of *Mentha arvensis* were planted, and considerable production was achieved. (106, 260) A synthetic menthol was developed, prepared by a distillation process starting with thymol. This synthetic has the same taste and odor as the natural product with only very slight pharmaceutical differences, if any. (89)

3. Quinine and Substitutes

With the loss of our primary sources of quinine in the Far East, expeditions were sent into South America to find new sources of cinchona (31). Large plantings of cinchona trees were made in Mexico and elsewhere in Latin America and it was believed that these would be a valuable source of quinine. (73) Georgia bark (*Pinckneya pubens*) yields an alkaloid similar to quinine, and this may be a valuable source of an antimalarial agent. The bark has been used for many years in the rural areas of South Carolina, Georgia, and Florida as a febrifuge. The tree grows plentifully in the swamp lands of these states. (51) Various synthetic drugs have also been developed to combat malaria. (134)

4. Miscellaneous Developments

a. Antibiotics. Penicillinlike substances hostile to germ life may be found in the leaves, fruits, and other organs of a wide range of higher plants. Antibiotics have been found in the leaves of Scotch thistle, mullein, and peony, and in the fruits of the blueberry currant, mountain ash, and honeysuckle. (53) Buttercup juice has also yielded a penicillinlike material. The growth of streptococci, staphylococci, pneumococci, anthrax and tuberculosis bacilli, and a
number of other microorganisms causing sickness in humans was stopped by the juice pressed from the leaves, stems, and blossoms of the buttercup. However, certain components of the juice were found to be toxic to laboratory animals. (11) Cabbage juice has been found to have germicidal properties, also (24).

Onion paste has been found to be effective as a dressing for open wounds. The essential oils of onions, garlic, and other strong-scented vegetables contain substances that kill bacteria, protozoa, and even larger organisms like yeast cells and eggs of lower animals. (99)

b. Blood Plasma Substitutes. A solution of hydrolyzed proteins enzymatically digested from beef blood plasma or casein has been suggested as a possible substitute or supplement for blood plasma for the treatment of shock from hemorrhage (113).

c. Rutin. Rutin, therapeutically useful in the treatment of increased capillary fragility, was found in flue-cured tobacco. It can be obtained as a byproduct from tobacco processing. (187) Rutin has also been found in two varieties of eucalyptus (247).

D. Waxes, Gums, and Resins

1. Waxes

The wide expansion of the uses of waxes, gums, and resins brought on by World War II and the loss of some sources of supply contributed to a condition of widespread scarcity of most items. The shortages of this class of products which occurred during the period covered by this survey are given in Table IV. The main problem during the war was the lack of shipping space for importing many of these materials. This was especially true of carnauba, which is imported from Brazil. Substitutes for many waxes were developed.
### TABLE IV
SHORTAGES OF WAXES, GUMS, AND RESINS, 1930-45

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<tbody>
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<tr>
<td>Balm of Gilead</td>
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<tr>
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<td>Copal Gums</td>
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<td>Damar Gums</td>
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<td>Elemi Gum</td>
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<tr>
<td>Fir Balsam</td>
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<td>Gum Guaiac</td>
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<tr>
<td>Gum Rosin</td>
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<tr>
<td>Gum Tragacanth</td>
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<tr>
<td>Irish Moss</td>
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<tr>
<td>Karaya Gum</td>
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<td>Kauri</td>
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<td>Kino Gum</td>
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<td>Locust-Bean Gum</td>
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<tr>
<td>Mastic Gum</td>
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<tr>
<td>Myrrh Gum</td>
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<td>Oakmoss</td>
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<td>Olibanum Gum</td>
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<td>X</td>
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<tr>
<td>Peru Balsam</td>
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<tr>
<td>Pine Tar</td>
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<td>Rubber</td>
<td></td>
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<tr>
<td>Sandarac Gum</td>
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<tr>
<td>Shellac</td>
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<tr>
<td>Tolu Balsam</td>
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</table>
a. Cauassu Wax (Calathea lutea). The extraction of cauassu wax is a valuable but undeveloped industry in Brazil. The plant, which resembles a small banana tree, flourishes near streams principally in the highlands of the state of Para. The leaves have been used extensively to make containers for sugar, flour, and other products and as a wrapping for fresh meat.

The wax is found on the underside of the leaves and is said to be equal in quality to carnauba. About 670 leaves would be necessary to yield one pound of wax, according to some calculations. The plant is a perennial and new leaves begin to develop as soon as the mature leaves are cut down. Its harvesting is less difficult than that of carnauba because the plants are smaller and the leaves are easier to reach. Improvements over the methods of hand extraction in common use must be made if the wax is to be put into commercial production, since much of the wax is lost through hand extraction. The wax has the following characteristics: melting point, 78°-80° C; specific gravity, 0.9735; acid number, 11.8; saponification number, 20.6-24.5; iodine number, 13.4; soluble in benzene, chloroform, carbon tetrachloride, glycol; slightly soluble in ether and petroleum ether. (20, 28, 208)

b. Jojoba Wax (Simmondsia chinensis). The seeds of jojoba yield a liquid wax which, upon hydrogenation, gives a hard crystalline wax which is said to be a good substitute for carnauba. Work is currently being done at this institution to determine the market potential for Simmondsia.

c. Green Cotton Wax. A freak variety of cotton that is green instead of white yields a wax which can be used as an extender of other
vegetable waxes for polish formulations. The wax is high melting and would be suitable for polishes for autos, furniture, floors, and similar protective coatings. (96, 157)

d.  Coconut Oil Wax. The crude residue from coconut oil manufacture has been purified by melting, filtering, dissolving the residue in hot benzene, treating with decolorizing charcoal, and filtering. The filtrate was then treated with talcum to remove carbon particles, crystallized in an ice bath, filtered, and the crystals dried and washed with acetone. The melting point of the wax so obtained was 93°-96° C. It can be used in floor wax, furniture polish, leather polish, and in other formulations. It is not a glyceride; after saponification the residue appears to be a wax containing the myristyl ester of cerotic acid. (259)

e.  Flax Wax. This wax has been produced experimentally from flax in France, Germany, and Ireland. Flax wax corresponds closest to beeswax, from which it is distinguished by a slightly lower saponification value, a higher iodine number, and a distinctly higher melting point. (158)

f.  Sisal Wax. The waste of sisal (Agave sisalana) yields, among other useful products, a wax having a melting point of 180° F. and closely resembling carnauba wax. The wax has a fine luster but the color could be improved. (29)

g.  Synthetic Waxes. Several synthetic waxes have been developed. Synthetic waxes as replacements for natural beeswax have been made available for use in the manufacture of cosmetics and pharmaceuticals. They are said to form stable and homogenous emulsions and creams when used in place of the natural wax. A comparison of chemical and
physical properties indicates that these synthetic replacements have properties practically identical with those of natural beeswax. (35) Substitutes for carnauba wax have also been developed; these are largely intended as supplements to carnauba rather than complete replacements. (2, 25, 81, 92) Japan wax can be replaced by "Nipocer," a synthetic wax manufactured from domestic materials. It is a tan-colored wax with a melting point of 46°-49° C and blends well with most waxes and resins. (139)

2. Gums and Resins

Substitutes have been developed at various times for almost all of the commercially used gums and resins. Gelatin (from animal sources) can be used as a replacement for gums in many cosmetic formulations. Gelatin has definite advantages and disadvantages depending on the type of preparation in which it is to be used. The viscosity will vary greatly with temperature if much gelatin is used; also, bacteria and molds frequently develop in the gelatin. However, gelatin is far superior to any of the gums in protective colloid action, emulsifying ability, and adhesive ability. (263) Extractives of some American woods are useful. Eastern larch contains an arabogalactan in substantial quantities. Gum of black cherry contains prussic acid and is similar to gum arabic. A gum similar to this is obtained from the plum. (172) A waxy corn has been developed which yields a starch which can substitute for tapioca, obtained from the root of the tropical cassava plant. Tapioca is used in the manufacture of gums, mucilages, adhesives, wood glues, and for cloth and paper sizings. (219)
Phase Report No. 1, Project No. 177-170

a. Agar and Algin. Agar and algin are both colloids which are obtained from seaweed. During World War II these materials were obtained from seaweeds grown off the North American coasts. The agar and algin obtained from these weeds was in every respect equal to the imported material in quality. (266) Algin was substituted for many vegetable gums and for moss extracts (6). A soap, in both liquid and paste forms, was made from kelp on the West coast of the United States (128). Sodium cellulose glycolate was produced in Germany as a substitute for gum arabic, agar-agar, and gum tragacanth. (164)

b. Gum Benzoin. Siam and Sumatra varieties of gum were used as substitutes for gum benzoin (189). A synthetic gum benzoin was produced on a commercial scale during the war. Its properties were similar to those of natural benzoin, and it had a sweet, balsamic odor, a sweet taste, and an amber color. (88)

c. Irish Moss. Irish moss can be substituted for agar for many canning purposes. New methods for extracting the jelling substance from Irish moss were developed; these yielded jellies stronger than agar with a discernible difference in taste. Irish moss was also used to prepare a sugarless syrup for sweetening purposes. (65, 85, 213)

d. Jatoba Gum. This gum is frequently known as the "Brazilian Damar" resin. It possesses physical characteristics similar to those of damar. Hard jatoba is used in making varnishes for exterior use, as it is resistant to sun, rain, heat, and cold. It can be mixed effectively with African resins, which are still harder. Jatoba is collected from trees (Hymenaea courbaril) growing in the states of Bahia and Minas Geraes. (67)
e. Locust-Bean Gum. Locust-bean gum has been mentioned as a substitute for gum tragacanth. Its price is rather high, but it reaches the consumer in better condition. Guar (Cyamopsis tetragonoloba) yields a gum which shows promise as a substitute for locust-bean gum. It is especially useful as the source of a mannogalacton mucilage in paper manufacture. (234, 248)

f. Rosin and Turpentine. The trend of rosin and turpentine production has been downward for many years, mainly because of these factors: (1) a decrease in the size and number of trees available for turpentining, (2) increasing competition from other raw materials, notably mineral spirits and wood naval stores products. Chemical methods of stimulating the production of naval stores by trees have been used to a large extent in some localities. The spraying of open slashes on the tree with dilute acid solution stimulates the production of turpentine and rosin to a very large extent. Increased plantings of slash pine were also made, and breeding for higher yields was carried out. (194)

Several new uses for rosin were found; Pentalyn M, a modified pentaerythritol ester of rosin, contributed to the conservation of critical drying oils, phenol, and glycerol (180). Rosin was also used in soaps to replace some of the critical oils and fats (201).

g. Rubber. When our main sources of rubber in the Far East were cut off at the outbreak of World War II, rubber became one of the most critical of our raw materials. Attempts were made to develop sources of rubber in the Western Hemisphere without too much success. Some rubber was collected in the Amazon Basin, but disease, great distances which make transportation costly, lack of sufficient food and fuel, poor
soil, and the fact that rubber trees only average one to the acre of
difficult jungle country all tend to make the collection of rubber in
the Amazon basin extremely difficult (221).

Many other plants besides Hevea were investigated as rubber sources.
Several have been mentioned in a previous report; among these are guayule
and kok-saghyz (8, 252). Others are discussed below.

(1) Chilte. The chilte tree (Cnidoscolus elasticus),
which grows in the mountains of Durango, Mexico, was investigated and
found to be a possible source of rubber, a resin suitable for hard sur-
face coatings, and a vegetable oil. The rubber (about 55 per cent of
the dry gum) is of superior quality. Tests indicate that the species
will not survive a temperature below 30° F. (230)

(2) Cryptostegia. This is a flowering vine which grows
in California, Mexico, and Central America. The quality of the rubber is
said to compare favorably with that of Hevea. Its cost, however, is so
high that it is unlikely that it could compete with other varieties of
natural rubber, but it offers certain advantages as a specialty
material (78, 223).

(3) Goldenrod. Rubber has been successfully extracted
from goldenrod by the Southern Regional Research Laboratory. Projects
to increase the yield of rubber have been undertaken. (54, 55)

(4) Johnson Grass. A patent has been taken out for
making rubber from Johnson grass, which grows wild in many parts of the
United States. Claims are that the rubber vulcanizes readily and can be
manufactured more cheaply than petroleum-base synthetic rubbers. Five
crops of the weed can be harvested annually. The weed is crushed in a
roller press; two pounds of grass yield one pint of juice. The juice is treated with linseed oil, ground glue, powdered sulfur, and lampblack for 90 minutes at the boiling point, then allowed to stand for twenty-four hours, after which it can be processed similarly to crude rubber. (68)

(5) Milkweed. The milkweed plant yields a soft, tacky material containing 25-40 per cent rubber hydrocarbon. The yield of latex from the leaves is about four per cent. A pilot plant was put into operation in Canada, and the process was said to show considerable promise. (186, 206)

(6) Rabbit Brush. It is said that some 25,000 tons of rubber could be obtained from the stems and roots of rabbit brush, a weed that grows thick on alkali flats and other wastelands of the West. This plant is similar to guayule, and the same methods may be used for harvesting both. The rubber would be too expensive for regular commercial production but could serve in an emergency. (149)

h. Shellac. Synthetic substitutes for shellac and lacquer were developed from several sources. A lacquer substitute has been prepared from tomato skins. The refined lacquer is soluble in alkalies and the usual solvents and provides elastic, lacquerlike protection for food cans. The lacquer is insoluble in solvents, organic acids, or hot water. (166) Zein has been used as a base for one shellac substitute. The substitute closely resembles shellac varnish in many respects. It can be applied by the usual methods, dries faster than shellac, and forms a hard, tough film. When applied to wood, it has a behavior intermediate between shellac and lacquer. The substitute is excellent as a label varnish and is highly resistant to moisture. (264)
Brazil has attempted to develop "goma laca" as a shellac substitute. This resin is obtained from pine knots from Rio Grande do Sul and has proved completely satisfactory in the manufacture of floor wax. It has been used in a mixture with equal parts of shellac on some inexpensive grades of furniture. (256)

i. Tragacanth Substitute. The shortage of high-grade gum tragacanth ribbon has caused many consumers to seek substitutes. One company offers "Gomagel," which is said to have the same viscosity and body in water as tragacanth. The substitute is a pure, white, edible protein powder made from domestic raw materials. (147)

E. Miscellaneous Materials

The shortages of miscellaneous items reported during the period covered by the survey are given in Table V.

1. Chemicals

a. Alcohols. Methyl, ethyl, and butyl alcohols were extremely short during the second World War. The widely increased uses of alcohols and alcohol products during the war were in large part responsible for the shortages. The supplies of molasses (the primary starting material for ethyl alcohol production) were insufficient to accommodate the increased needs, and new raw materials had to be found. Many materials were suggested as possible raw material sources. Among those suggested were grape pomace (235), pineapple (112), citrus peel (43), bananas and banana stems (3, 66), and potatoes (232). These were all emergency methods and were not widely exploited. In 1943 the alcohol being produced came mainly from three sources; molasses (15 per cent), petroleum (10 per cent), and grain (75 per cent). The grains used were corn, rye
## TABLE V

SHORTAGES OF MISCELLANEOUS MATERIALS, 1930-45

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<thead>
<tr>
<th>Item</th>
<th>1930-35</th>
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<td>Butyl Alcohol</td>
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<td>Caffeine</td>
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and wheat. (5) It was reported that a method of producing alcohol from wheat without the addition of malt has been developed. It was found that the diastase in granular wheat flour could be activated so as to convert its own starch into fermentable sugars without the presence of malt. (4)

Investigations of the possibilities of making alcohol from sawdust and other wood wastes gave favorable results. The process involves the acid hydrolysis of wood to sugar and the subsequent sugar fermentation to form alcohol. The economic possibilities of the process did not appear promising. (214)

Butyl alcohol was produced from surplus potatoes for a short time (23).

Glycerine was also extremely short during the war. There were two major reasons for this: (1) Needs of the military were tremendous, and glycerine is irreplaceable in many compounds. (2) Efforts to increase the supply of glycerine met with little success because of raw material shortages. (160) Materials tried as substitutes for glycerine included sorbitol, propylene glycol, invert sugar, corn syrup, 2-methyl 2-4 pentane diol, 1-5 pentamethylene glycol, sodium lactate, honey, apple syrup, propylene glycol borate, and methyl cellulose. (12, 143)

New sources of several other organic solvents were found. Acetone, methyl alcohol, methyl ethyl ketone, isopropyl alcohol and diethyl ketone were obtained as byproducts of esparto grass pulping (231). Phenol was obtained from a cashew nut shell liquid (111), and acetone was obtained from potato flour by a fermentation process (22).
b. Motor Fuel. Motor fuels have been made from vegetable oils (76) and from Douglas fir tar. It was said that some 25,000,000 gallons of motor fuel could be obtained from this waste from saw mills. (75)

c. Plastics. Plastics have been made from a wide variety of materials. Among these are lignin (173), corn protein (37), cotton (38), and jute (115).

d. Utilization of Waste Materials. Surplus potatoes were mentioned as possible sources of industrial alcohol and high-quality starch, and the stalks as sources of alkaloids and fiber or cellulose (117). Sawdust, wood shavings, and ashes have all been used as fertilizers and animal bedding materials (126, 163). Lignin has been investigated as a source of chemical products; among these are adhesives, absorbents, fuels, plastics, and molding compounds (267).

2. Foods, Spices, and Flavorings

The food materials which were extremely short during World War II were mainly the spices and other flavoring products and sugar and starch. Attempts were made to grow some spices in this country, but disparities in climate and soil immediately removed from serious commercial consideration some of the most important spices, such as cassia, cinnamon, cloves, ginger, nutmegs, and pepper. Most progress was made in the cultivation of anise, caraway, celery, coriander, mustard and poppy seeds, sage, and thyme. (196)

a. Caraway Seed. Caraway seed was grown successfully on a commercial basis in California. Yields of about 300 pounds per acre were obtained. (175)
b. Cinnamon. A cinnamon substitute was made from ground almond shells. The substitute was finer-grained, lighter-colored, stronger-flavored, and of similar appearance with respect to genuine cinnamon. (107) It was also reported that an artificial cinnamon had been made in Germany from a mixture of 96 per cent cinnamic aldehyde and four per cent eugenic acid incorporated in a three to four per cent powder carrier consisting of the pulverized shells of hazel nuts, almonds, or other nuts (52).

c. Cocoa Butter Substitute. By special processing, cottonseed oil can be converted into a substitute for cocoa butter. The physical differences between the two are minor; the substitute has a slightly longer plastic range, supercools less strongly, and contracts slightly less when solidified. (32)

d. Paprika. Paprika (Capsicum frutescens) was grown successfully in California. The quality of the fruit was said to be superior to that of the imported article. (179)

e. Sugar. Shortages of sugar led to a search for new sources of sugar and for sugar substitutes. By discovering means of removing starch and aconitic acid from the juice of the sorgo plant, used extensively for making sorghum syrup, scientists of the United States Department of Agriculture were able to develop a method for obtaining a satisfactory yield of sugar crystals which could be made into refined or granulated sugar (133). A sugarlike product suitable for use in confections was made from sweet potatoes (138).

3. Insecticides

The increased military demands during World War II contributed largely to the shortages of the more important insecticides, as shown in
Table V. Pyrethrum and rotenone were especially short. The development of several synthetic insecticides, of which DDT is the most important example, did relieve shortages to some extent.

a. Pyrethrum. The United States Department of Agriculture developed a pyrethrum harvester, which removed one of the main bottlenecks to growing pyrethrum in this country. There were other difficulties, however, such as hand labor costs, and the commercial production of pyrethrum was never successful. (122) It has been found that sesame oil with pyrethrum extract in kerosene is very effective against houseflies. (245)

b. Rotenone. Substitutes for rotenone were various inorganic chemicals or other vegetable products such as pyrethrum. Several species of the genus *Tephrosia* (some sources say *Cracca*) are substitutes when rotenone prices are high; otherwise the rotenone content is too low or too variable to have any interest. One strain, *T. (Cracca) virginiana*, has been found to contain five per cent rotenone in the roots. This species, also known as "devil's shoestrings," grows from southern New England to Florida and west to Minnesota and Texas. (40, 207)

c. Insecticide from Castor Plant. The toxins of the castor plant have yielded an insecticide known as "Spra-Kast." It is specific for combatting scale infestations, certain mites, and spiders. (244)

d. Yam Bean Insecticide. The Chinese yam bean, which is cultivated in Central America and Mexico for the food value in its roots, is the source of a promising insecticide which is said to have many of the values of rotenone insecticides. It has been proved effective in killing pea aphids, Mexican bean beetles, and other pests. (61, 167)
e. Other Possible Insecticides. Several synthetic insecticides have been developed; most of these were related to Lethane or DDT (86, 120). Other plants which have shown some promise as insecticide sources include tree tobacco (*Nicotiana glauca*), which is a worthless weed growing in Mexico and the arid American Southwest (63, 258); balbina, which grows in Peru (15); southern pine, which yields "Thanite," similar to pyrethrum in many respects (62); and several Chinese plants which were collected along the Burma Road in southwestern China (215).

4. Tannins

The shortages of tanning materials reported during the period covered by this survey are given in Table V. Of the commercial sources of tannin, extensive areas of red mangrove were found along the Mexican Gulf Coast. The bark of this tree contains 20-40 per cent tannin. (205) Several new tannin sources were discovered, and synthetic tannin replacements were developed. "Orotan" is an example of the latter. (90)

Among the domestic plants mentioned as possible sources of tannin are buttonwood, western hemlock, darling-plum, and palmetto (91, 146, 249).

Several Indian trees have been mentioned as possible sources of tannin. The bark of *Hopea parviflora* yields a solid extract containing 66 per cent tannin. The tree is used for other purposes, however, and the supply available for tannin is limited. (241) The leaves of *Anogeissus latifolia* have yielded 33 per cent tannin in laboratory tests. Samples of Indian sumac have yielded 39 per cent tannin. Leather tanned with the last two materials mentioned was of light color and high quality. (242)
V. CONCLUSIONS AND RECOMMENDATIONS

After reviewing the results, it is believed that the procedure used in the literature investigation has been satisfactory for obtaining the information desired. The survey has indicated that there have been widespread shortages of many plant raw materials necessary to industry. This has been most noticeable during the years of World War II. Shortages previous to World War II were mostly seasonal or the result of crop failures, but the shortages during the war demonstrated the very great dependence of the economy of this country upon external sources of supply for many plant raw materials.

Among the most critically needed fats and oils were drying oils, particularly those containing conjugated unsaturation. Almost all of the more commonly used essential oils were in very short supply; many were unobtainable. The need for a domestic source of lauric acid oils, such as coconut and palm oils, was also found.

The most critical shortages of fibers and wood products included both cordage fibers and wood pulps for paper manufacture. Bristles of the quality necessary for the manufacture of paint brushes were also extremely difficult to obtain.

Shortages of many drug and pharmaceutical products were noted. Those of the greatest consequence were atropine, ergot, quinine, menthol, digitalis, and stramonium.

Carnauba wax and substitutes for it and other hard waxes were in extremely critical supply. Many water-soluble gums and vegetable resins were in inadequate supply throughout the war. Rubber latex was obtainable only in very minute quantities, and synthetic rubber became an important substitute.
Other materials which were reported as being in extremely short supply were alcohols (especially ethyl alcohol), glycerine, black pepper, insecticides of the pyrethrum and rotenone types, and tannins.

This survey has revealed numerous plants which may have potential value as sources of substitutes or as replacements for products critically short during times of emergency.

It is not believed that an extension of the literature survey further into the past would yield sufficient additional information to warrant the expenditure of time and effort necessary to secure it.
VI. APPENDIX
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PART II

1952
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I. INTRODUCTION

A review of the literature was undertaken as a part of the program initiated at Georgia Institute of Technology by C. O. Erlanson, Head of the Division of Plant Exploration and Introduction, Bureau of Plant Industry, Soils and Agricultural Engineering, United States Department of Agriculture, to determine the recognized or published needs for raw materials from plant sources. A secondary object was to locate published information indicating new crops that might have economic value.

This part, which covers the year 1952, in conjunction with the literature survey report submitted under Contract No. A-1S-33022 and Part I of this survey, represents a comprehensive literature survey concerning plant raw materials mentioned in the journals examined covering the period January 1, 1930 through November 30, 1952.

II. PROCEDURE

The procedure used in the survey of the current literature was substantially the same as that used for the survey reported in Part I of this report. The complete list of journals examined in this survey is given below. All were examined for the period January 1, 1952, through November 30, 1952.

(1) American Paint Journal
(2) American Perfumer and Essential Oil Review
(3) Business Week
(4) Chemical and Engineering News
(5) Chemical Engineering
Phase Report No. 1, Project No. 177-170

(6) Chemical Week
(7) Chemurgic Digest
(8) Drug and Cosmetic Industry
(9) Economic Botany
(10) Foreign Commerce Weekly
(11) Journal of the American Oil Chemists' Society
(12) Naval Stores Review
(13) Oil, Paint and Drug Reporter
(14) Paint Manufacture
(15) Paint, Oil and Chemical Review
(16) Science News Letter
(17) Soap and Sanitary Chemicals
(18) Textile Technology Digest
(19) Tung World

Several standard indexes were covered for the recent issues which were available. These were:

The Agricultural Index, (January–November, 1952)
The Industrial Arts Index, (January–November, 1952)
III. CLASSIFICATION OF RESULTS

The disclosed needs were classified into these general categories:

A. Fats and Oils
B. Fibers and Wood Products
C. Drugs and Pharmaceuticals
D. Waxes, Gums, and Resins
E. Miscellaneous Materials

Specific items from each of the above classifications, considered to be of special interest because of continued shortages or importance to industry, were screened for discussion. Those new materials discussed in some detail in the reports on the literature surveys covering the years 1930-51 (Final Report, Contract No. A-1S-33022, and Part I of this report) are not discussed here except in those cases in which further information has been obtained.

IV. DISCUSSION OF RESULTS

A. Fats and Oils

1. Fixed Oils

Developments in the fixed vegetable fats and oils for the first seven months of 1952 have been discussed in a bulletin published recently by this Station.*

A new process for solvent-extracting oil from cottonseed and other oilseeds has been developed on a pilot-plant scale at the Government's Southern Regional Research Laboratory. The process, which is especially

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adapted for use by small mills, is called "filtration-extraction" because it involves the use of a continuous vacuum filter as the major operating unit. It has been operating successfully with cottonseed and, with certain modifications, it has also proved to be suitable for the oil processing of rice bran and soybeans on a pilot-plant scale. Experiments with other oilseeds are under way. (34)

a. Drying Oils. The drying oil situation was highlighted by shortages of tung oil during the greater part of the year. Supplies of tung oil are expected to be adequate during the coming season. The loss of Chinese supplies has been offset by increasing imports from Argentina, Paraguay, and Brazil and by the tremendous increase in domestic production. (80) There was also general dissatisfaction among soybean processors because of unfavorable ceiling prices, and this condition caused many producers to stop production during the year. Otherwise, drying oils were in generally good supply.

(1) Soybean Oil. The development of a new variety of soybean, called Perry, has been announced as a full-season variety for southern Indiana, southern Illinois, central and southern Missouri, and eastern Kansas. It is reputedly a high-yielding type, and the beans are of high oil content. All seed from the 1951 crop has been allotted to seed producers for increase, so there will be plenty of seed for planting in the 1953 season. (56)

Phytic acid, an ingredient of many grain seeds, is a good stabilizer in preventing off-flavors in soybean oil. As little as one-half pound of phytic acid added to one ton of soybean oil will lengthen the storage life of the oil by preventing the development of off-flavors.
Phytic acid is the hexaphosphoric derivative of inositol and occurs in nature as the calcium salt. (62)

A high-frequency oscillator can measure the soybean oil in a solution of standard solvent in 15 minutes, compared with several hours required by the present method. The soybeans are first ground with the solvent in a special grinder-extractor. After filtering, the solvent-oil mixture is placed in the cell of an electric oscillator which measures the dielectric constant. The reading is then converted to per cent oil with a table which was prepared by analyzing many samples by the old method. Two analysts can make 20-30 determinations per hour. If the equipment is used at capacity, the estimated cost is claimed to be about one-half that of the equipment needed for testing by methods now in use. (52)

(2) Tung Oil. Eleostearic acid, obtained from tung nuts, can be used as a tracer to follow the absorption of fat by the blood. This new, rapid method of tracing fat absorption may contribute to a better understanding of diseases of the liver and of such diseases as sprue, jaundice and arteriosclerosis. (81)

(3) New Drying Oils

(3.1) Grapeseed Oil. The oil pressed from the seed of wine grapes has been used in the paint industry in Italy for 20 years and could probably be made available in this country. It could play an important role in the protective coatings industry when other fatty oils are scarce. The oil has a slightly higher viscosity than linseed oil and, when pigmented with zinc oxide, yields paints of better moisture impedance than corresponding linseed oil paints. (40)
(3.2) Kamala Oil. Indian scientists are investigating kamala oil, which is said to be a substitute for tung oil. The oil, extracted from the seeds of a small evergreen tree (*Mallotus philippinensis*), dries to a natural wrinkle-finish without the application of heat. The oil is generally better than tung oil, and the seed has an oil content of about 40 per cent. The seed has long been familiar as the source of an orange dye. Previous development as an oil crop has been hampered by the oil-extraction process involving expensive organic solvents. (64, 82, 94)

(3.3) Safflower Oil. Safflower oil is already well into the commercial market, but interest in its cultivation in the United States is of fairly recent date. Stand oils prepared from safflowerseed oil have been found to be similar to the corresponding linseed oil products (119). The oil also has good drying properties when otherwise prepared (123). Safflower oil bleaches considerably better than linseed oil and is equal to or better than soya in this respect (117).

(3.4) Other New Drying Oils. Several other oils have been mentioned as possible substitutes for drying oils. Among these are Lynstrol (a synthetic based on linseed oil and styrene) (68), niger seed oil (114), oil from the seeds of *Abutilon indicum* (105), gokhru oil (54, 58), pilchard oil (99), and oil from the seeds of *Stillingia sylvatica* (97).

b. Other Oils. Of the fixed oils, exclusive of drying oils, only scattered shortages were reported. There were some shortages of coconut oil and castor oil in the summer months, as well as a shortage of peanut oil which was a result of the drought this past summer.
Components of various frozen deserts may provide a new outlet for vegetable oils. These deserts are inexpensive ice cream imitations in which low-priced vegetable oils replace expensive butter fat. The new product is processed, manufactured, stored, and handled with the same equipment used for ice cream. It is estimated that about 1.1 million pounds of fats and oils could be used annually for this purpose. Oils that have been used for this purpose are cottonseed, soybean, coconut, and peanut. (86)

(1) **Castor Oil.** Castor oil is used as the plasticizer in a new, lightweight material consisting of a nitro-cellulose-based compound on cotton sheeting. It has certain advantages over ordinary oilcloth. The material is washable, stain- and ink-resistant, and waterproof. (19)

A substitute for castor oil has been developed by Spencer Kellogg and Sons. Known as "Kelcastol," it has many of the properties of ordinary castor oil, i.e., it is nondrying and of a light color. It is a modified vegetable oil (but not based on castor oil) and will be cheaper than castor oil. (18)

(2) **Coconut Oil.** A new, patented process for obtaining coconut oil directly from the fresh coconut has been adopted and used in the Philippines since early this year. Although the Philippine plant is capable of extracting about 5.5 short tons of coconut oil from some 40,000 fresh coconuts, the commercial possibilities of the new process are not yet known. Should the present operation prove successful, similar plants will be constructed in other places. With the new process, which eliminates the necessity of first producing copra, a high-grade coconut oil is reportedly obtained. Since the free fatty-acid content is less
than 0.10 per cent, the oil needs no refining. However, deodorization with steam, if only to destroy the organisms causing fermentation, is necessary if the oil is to be stored. (61)

(3) Cottonseed Oil. Several new food products have been developed from cottonseed oil. Among these are a meat-flavored sauce, a nutlike filler for candies, and a cheese-type curd from the protein. (112)

(4) Palm Oil. The possibilities of producing palm oil in Honduras have been investigated at some length. Selected varieties of oil palms from Africa, the East Indies, and the Malay States were planted; the Java variety was found to be the highest yielding. (116)

A new stripping oil medium developed by Archer-Daniels-Midland Company is said to offer important economies and improved results in the hot-dip tin and tin-plating industries. The new composition overcomes the most serious objections to palm oil and other traditional stripping oils. Under the high temperatures at which oil stripping is usually done, palm oil gradually decomposes and increases in body viscosity. It generally becomes necessary to replace at least 25 per cent of the oil every two weeks to maintain satisfactory performance. In contrast, the new material is said to be so stable that decomposition is negligible. After a six-month test it still retained all the original properties required of a satisfactory stripping oil. No additions were necessary except to replace the oil carried away as film on the finished product. (5)

(5) Peanut Oil. Peanut oil is being mixed with high-grade Diesel oil for use as an experimental tractor fuel in India.
The experiment resulted from the threatened petroleum shortage caused by trouble in Iran. A highly-refined peanut oil was used in an International Harvester unit. There was no starting trouble and the engine ran smoothly. However, toward the end of the 50-hour experiment, smokiness developed in the exhaust and oil consumption increased. Further experiments are planned, but there is little chance of the expedient's being widely used unless the price of peanut oil goes down. (59)

(6) New or Little-Used Oils

(6.1) Avocado Oil. Oil from the Fuerte variety of avocado grown in Kenya, after removal of the petroleum ether solvent used to extract it, has been reported to compare favorably with the American commercial grade. The average oil content is about 18 per cent. The oil would be suitable for use in soaps and cosmetics and, after bleaching, as an edible oil. (47)

(6.2) Rice Bran Oil. A recent development in the oil industry is the recovery of oil from rice bran. About ten per cent of rough rice is milled out as bran containing 15-17 per cent oil. The oil is stable, odorless, neutral, and more resistant to oxidation than the average cooking oil. Several plants for recovering the oil have been placed in operation, and more are planned. (65, 110)

(6.3) Sesame Oil. For the past five years an intensive research program has been under way to develop new strains and varieties of sesame. This oilseed yields more oil to the acre than any other annual oilseed. In the past it has not been amenable to mechanical harvesting because of its tendencies to ripen unevenly and to drop its seed at maturity. This oil has many possible uses and is now being
used for making shortenings, cooking oils, and margarine, and in soaps, drugs, paints, and insecticides. The pressed cake or meal makes an excellent livestock feed because of its high protein content. The oil and seed keep for several years without becoming rancid. New, nonshattering varieties of the plant have recently been developed, and trial field-plantings have been made during the past few years. The present oil mills of the south could, with only minor modifications, be equipped to extract oil from the sesame seed. (111)

(6.4) Sorghum Grain Oil. Sorghum grain was found to contain as much oil as corn and 50 times more wax. The grain oil was found to be similar to corn oil and could be used as a substitute for salad oils or hydrogenated and made into oleomargarine. (108)

(6.5) Other New Oils. An estimated five million pounds of black spruce oil could be obtained from Canada if new uses could be found. Black spruce oil is one of the richest natural sources of bornyl acetate. It may also be used for synthetic camphor. (120)

Certain Indian oils have been mentioned as possibilities for commercial development. These include pisa fat, which is almost pure trilaurin; nim oil, which may be of pharmaceutical interest; mowrah oil, which is said to offer special advantages by way of hydrogenation; and khakan and phulwar oils, which might serve as coconut oil substitutes. (25, 54, 58)

Some of the fruit pit oils, such as apricot, peach and prune, have been mentioned as being of possible use in the cosmetic and pharmaceutical industries. (107)
Some vegetable fats can be produced by micro-organisms such as the strains found in *Penicillium*, *Aspergillus*, *Endomyces*, and others. Submerged culture methods allow batch pilot-plant-scale production. No microbial process has been developed to date that can compete economically with edible fats derived from plants or animals. The cost of microbial processes runs from three to ten times higher than the conventional methods, but the process may be important in times of emergency. (118)

2. Essential Oils

The supplies of many essential oils during the year 1952 have been becoming smaller because of the strained international situation until at the present several are in critical supply.

a. Oil of Anise. Star anise (*Illicium verum*) supplies have been gradually getting smaller with each passing month, and there is very little hope of replacement since the only source of supply is the Chinese mainland. Anethol, the chemical substitute, has generally been freely available. (3, 4, 9, 10)

b. Oil of Bergamot. Bergamot has been extremely short during 1952, mainly because of a small crop during the last growing season (30).

c. Oil of Cassia. Cassia has been in the same situation as anise. Replacements from China have been unobtainable, and shortages of this material have gradually become more acute. (3, 4, 71)

d. Oil of Clove. During the latter part of 1951 a shortage of clove oil loomed which, by March, 1952, was seriously crippling the industry, and distillers were cutting their operations tremendously. Cutbacks continued until practically no distillers were operating. This
predicament was caused by the Office of Price Stabilization's setting so low a ceiling price on the oil distilled in this country that it has been impossible to import the clove buds and manufacture the oil at the present price of the imported cloves. (2, 3, 103)

e. Other Essential Oils. Oil of ylang ylang and Bulgarian rose oil are also short for similar reasons. It is unlikely that these oils can be obtained so long as the present strained international relations exist.

Several oils were mentioned as being short for seasonal reasons; these were grapefruit, lemon, lime, spearmint, and wormseed.

f. New Developments. Corn smut in aerated submerged cultures produces a mixture of glucolipides (designated as the ustilogic acids in yields of 10 to 15 grams per liter of fermentation mixture) which exhibits strong in vitro antibiotic properties. The acids are mixtures which can be resolved by crystallization and acid oxidation followed by esterification and fractional distillation. The end product, the dimethyl ester of pentadecanoic acid in 55 per cent yield, is used to make a synthetic musk known as exaltone.

The leaves of Lippia carviodora from Somaliland have been processed to evaluate their commercial possibilities as a source of volatile oil. The sample tested yielded 3.15 per cent of an oil having a d-carvone content which compared favorably with that in caraway oil. (69)

B. Fibers

There seemed to be very few shortages of the fibers during 1952. At the first of the year it was thought that there might be a shortage of cotton, but a slump in the textile market makes this unlikely.
1. Natural Fibers

a. Flax. It has been found that a bacterium (Clostridium felsineum) present in Belgian flax aids the fiber separation when placed in a retting bath of Australian flax. The fibers produced by this method are up to three grades better than previous Australian fiber in quality. An attempt is now being made to find an economical way of introducing the bacteria into retting solutions so that the peacetime growing of Australian flax will be economically feasible. (93)

b. Hemp. The United Fruit Company is expected to get 35,000,000 pounds of hemp out of the Central American jungles. That amount just about meets the United States' defense needs for this fiber. (84)

c. Kenaf. The Florida plantings of kenaf in the summer of 1951 proved the feasibility of growing kenaf on a commercial basis in the United States. Although the crop was planted late in July and carried over into the hurricane season, the results obtained justified the risk. There is enough land in one county of Florida alone to produce enough kenaf fiber to equal, and even to exceed, the entire annual tonnage of jute imported from the Orient. Kenaf can be grown in all the Gulf states. Decortication has always been a problem, but efficient machines have now been developed for this purpose and further improvements are being made. Success of the kenaf program will depend upon sufficient capital and initiative to make use of the seed available. (106)

d. Ramie. Recent production of ramie in the Everglades of Florida has shown that ramie can be produced successfully and indicates
that, with a little planning, it could be produced and degummed in Florida for a much lower price than cotton. It is estimated that well-established ramie plantings on Everglades peat will provide at least three cuttings per year unless there are several climatic interferences. A conservative estimate places the yield of degummed, bleached fiber at 1,200-1,500 pounds per acre per year. (1)

2. Synthetic Fibers

The Defense Production Administration has set up a three hundred million pound yearly production goal for noncellulosic fibers by 1956—an increase of two hundred million pounds over 1951. (33)

A new synthetic ceramic fiber called "Fiberfrax" has been developed. It will probably find its way into industrial applications as a replacement for asbestos. This synthetic is produced by melting aluminum oxide, silica, and certain modifying agents at 3,300° F. and blowing the molten material into a random arrangement of fine fibers. It resists temperatures as high as 2,300° F., has good filtration properties, resists attack by most chemicals, and is resilient and light in weight. (21)

A bristle-type fiber has been developed from casein; this fiber is being used in automobile carburetor air filters and for mattress stuffing. There is a large potential market for the fiber for furniture stuffing, paint brushes, and in the manufacture of stiff cloth. (124)

A method for converting chicken or turkey feathers into a product which can be woven into cloth or pressed into felt has been developed. The fiber resembles a cross between silk and wool. Its dye qualities resemble those of silk and its weight is about one-third that of wool. (31)
3. Wood and Paper Pulps

The Hawaiian Sugar Planters Association is backing research to further the utilization of sugar cane fiber in pulp and paper products (78). Pilot-plant studies by the National Bureau of Standards have shown that a satisfactory newsprint can be made from sugar cane bagasse at very low cost (104). A process for making paper pulp from banana stump bagasse is being investigated in Brazil and India (113). The Herty Foundation has developed a low-pressure, low-temperature cooking technique that uses waste wood from paper mills to produce paper with high resistance to tearing and bursting (87). The woody portion of the flax stem is being used to make a rough, brown wrapping paper by Kraft and Company (38).

Synthetic sponges are being made from viscose, a gummy wood-pulp derivative that also goes into rayon, cellophane, and many plastics. The sponges have some qualities superior to those of natural sponges. (91)

A bagging material made of jute impregnated with synthetic rubber has been developed in West Germany. The bag is pliable and crack-proof and is impervious to most industrial chemical products. (12)

An Oregon lumber company has opened a slab-wood plant capable of producing 120,000 square feet per day of a new-type hardboard. The process requires no chemicals. The slab-wood from lumber mills (slabs of bark and wood cut from the outside of a tree) is cut into chips, sprayed with steam for one minute, and sent through a "defibrator" which loosens the fibers. The resulting pulp from the fibers is formed into sheets, pressed, and dehumidified. The company believes that the hardboard thus produced is comparable in physical properties to older types of material. (53)
C. Drugs and Pharmaceuticals

The botanical drug industries have been hampered by shortages during recent months and it is possible that a heavy critical period will develop. In the Middle East, trade in such commodities as senna, colocynth, saffron, and quince seed has been hampered by hostilities in that area, and many regions now under Communist domination are no longer available for our trade.

1. Alkaloids

The Easter hydrangea is the source of a new alkaloid which has a promising future as an antimalarial. Laboratory tests have shown that the drug is many times superior to quinine. A derivative of this alkaloid has been developed which shows greatly increased effectiveness. (11, 41, 77).

Morphine has been synthesized by chemists at the University of Rochester. The process, however, is so lengthy and expensive that there are no practical applications foreseen. (50)

Three species of the Australian genus Duboisia contain alkaloids of some interest. Duboisia myoporoides and Duboisia leichhardtii contain hyoscine and hyoscyamine in high concentration. The former drug is used in childbirth and in psychiatry, and the latter is a source of atropine. Duboisia hopwoodii contains the tobacco alkaloids, nicotine and nor-nicotine. (96)

Protoveratrine, an extractive of green hellebore weed, can reduce high blood pressure for a period of six to eight hours without ill effects. However, it is not a cure for high blood pressure. Production of the drug is handicapped because the American species of this plant
does not produce as much protoveratrine as the species found only in the
Balkan countries of Europe. (89)

2. Blood Plasma Substitute

It is believed that a substitute for blood plasma has been
found in a new substance derived from red blood cells. The product
consists of proteins taken from red cells and prepared so that they can
be dissolved in the blood stream and can feed the body in the same way
that plasma does. Since red cells are largely wasted in the present pro-
cesses, the new substance is cheaper to produce than plasma and will in-
crease the protein yield of each blood donation by more than three times.
The protein part is said to be most valuable when plasma is given for
nutrition or to combat shock. (49)

3. Cortisone

There have been several new developments in cortisone produc-
tion this year. Hecogenin, a steroidal sapogenin found in the leaves
of sisal (Agave sisalana), is being investigated as a starting point
for the partial synthesis of cortisone. If the manufacture of cortisone
from this material is found to be economically feasible, there would be
no dearth of raw material. (28)

The dry byproduct leaf powder from yucca fiber may prove to be a
large-scale source of sarsasapogenin, a steroid which is considered to
be a potential cortisone precursor. Sarsasapogenin can be converted
into progesterone which is one of the possible starting points for a new
process involving microbiological oxidation. (55, 95)

Cortisone is to be manufactured from whale carcasses by a company in
New Zealand. (29) It is noteworthy that a total synthesis of cortisone
from readily available materials has been reported (35).
4. Miscellaneous Developments

An antibacterial cement for food processors and others whose products are heavy in bacteria has recently been developed. An active germicide incorporated in the cement is said to check permanently the bacteria that normally break down masonry. (20)

Adenylic acid, a waste product in brewing beer, is being used to relieve some of the painful symptoms of Hodgkins disease. The compound was originally extracted from the muscles of beef cattle and other animals at high cost, but the new method is far less expensive. (14)

An antitumoral agent has been extracted from dried juniper needles. It is believed to be related to podophyllotoxin and is possibly the previously unknown desoxypodophyllotoxin. (46)

A new, clinically promising, broad-spectrum antibiotic has been isolated from soil taken from the Philippines. It is called "Ilotycin" and has been proved effective against many penicillin-susceptible bacteria, plus the causative organisms of typhus, undulant fever, and Rocky Mountain spotted fever. Ilotycin has one very desirable feature—it produces no toxic after-effects. (60)

Citrus pulps are being utilized in the manufacture of medicinal tablets which require stability during storage and quick disintegration when taken internally. (24)

What may prove to be a new vitamin has been discovered at the United States Department of Agriculture's poultry nutrition laboratory. A concentrate prepared from fish solubles has been found to contain a factor that promotes rapid growth in young growing chicks—even those being fed all the known nutrients. The new factor is found in fish solubles, fish meal and meat meal. (36)
A twenty per cent to forty per cent honey solution injected intravenously has been recommended for young horses and other animals. The effects are similar to those of glucose solutions since it is an energy source. The honey solution is nontoxic and is claimed to increase an animal's resistance to infectious diseases. (43)

D. Waxes, Gums, and Resins

1. Waxes

Advancing prices of many vegetable waxes over the past few years have caused many consumers to look for substitutes for many of the hard waxes, especially for carnauba. The following materials have been mentioned as substitutes for carnauba wax.

a. Cauassu Wax. The leaves of the cauassu (Calathea lutea), a tall herb of the Amazon region, are potentially an important source of a commercial wax. The crop growth of this plant in semitropical areas of the United States is believed to be quite possible. Reports from Brazil indicate that the plant is easily grown and that the wax yield is very good. About 30,000 seedlings can be planted on one acre of land and can be harvested a year after planting. In subsequent years two harvests may be collected annually; this would mean a crude wax yield of about 800 pounds per acre annually. The wax is removed from the dried leaves by mechanical beating or extraction with hot water.

Preliminary tests indicate that the wax is similar to carnauba and can be used for many of the same purposes. It has the disadvantage of containing a resin which would require removal by solvent refining for some applications. (121)
b. Marrubium vulgare. The dry leaves of this plant were extracted with acetone and the evaporation residue was extracted with ether, from which, after cooling, marrubine was obtained. The mother liquor contains chlorophyll and waxy material. (98)

c. Simmondsia Wax. The hydrogenated oil of the Simmondsia plant is a hard, crystalline wax which has a melting point only slightly lower than that of carnauba. (113) At the Georgia Institute of Technology a group is currently conducting a survey to determine the economic potential of Simmondsia oil and wax.

d. Sorghum Grain Wax. Recent studies have shown that sorghum grain wax has characteristics similar to those of carnauba. The wax is concentrated in the hull or bran and can be extracted by fractional solvent extraction. An average yield of 0.32 per cent wax has been obtained from 14 varieties of sorghum. Sorghum grain wax has higher acetyl, acid, and iodine numbers and a lower saponification number than carnauba wax. Sorghum grain wax also contains a lower percentage of esters and non-saponifiable matter than carnauba, and a hydrocarbon fraction that is not present in the latter. (100, 108)

e. Sugar Cane Wax. Sugar cane wax is available in large quantity from sugar mill residues. Two processes have been mentioned for obtaining the wax. One, an American development, involves solvent extraction followed by bleaching. The other, developed in Australia, uses vacuum distillation followed by chromic acid bleach. The latter method costs more, but a more uniform quality of wax is obtained. (16, 38)

f. Synthetic Waxes. Several new synthetic waxes have been mentioned. Most of these use microcrystalline waxes as a starting point. (15, 57, 88, 109)
2. Gums and Resins

a. Agar and Other Seaweed Products. Three types of Philippine seaweed have shown promise as sources of agar. The product so far obtained is not up to the United States standards, but it is believed that better methods of processing would improve the quality. (61)

Laminarin, a derivative of seaweed, can be used as a substitute for talcum powder and may have possible use as a substitute for blood plasma and as a surgical powder. (67) Some antibiotics have also been found in various species of seaweed (90).

b. Gum Arabic Substitutes. A gum-type substance obtained from larch trees, which grow profusely in parts of the Northwest, is believed to be a possible substitute for gum arabic. The new substance, known as arabogalactan, can be produced competitively from trim ends, slabs, and other waste products of the saw-mill. The material is extracted chemically so that the waste can be used for fuel, pulp, or other purposes after treatment. The product is odorless, tasteless, and instantly soluble in water. (51)

c. Cashew Nut Shell Resin. The cashew nut shell yields a liquid resin that mixes with ethyl cellulose to form a binder that keeps powdered coloring particles on fabrics from rubbing off (17).

d. Gums for Drilling Muds. Iranian gums and gum-bearing seeds improve markedly the filtration characteristics of fresh-water muds, salt-water muds, and high-pH red lime-base drilling muds. Those gums tested were ghatti, tragacanth, shiras, quince seed, and locust bean. At elevated temperatures the effectiveness of gum shiras and locust-bean gum is even greater. (122)
e. Naval Stores. Gum turpentine has been found to yield terpene hydroperoxides which are particularly suitable for use as catalysts for the production of "cold rubber." The commercial production of these new chemicals, using gum turpentine as the raw material, would open a large new market to the gum naval stores industry. At the same time, the use of gum turpentine for this purpose would help to conserve the short supply of benzene, at present the raw material for the most widely used "cold rubber" catalyst. (85)

Tall oil has been found useful in flotation procedures for recovering valuable material from low-grade ores or waste solutions (76). It has also shown promise in certain types of organic protective coatings (115).

Other new materials which have been obtained from naval stores products are a high-quality synthetic lubricant from turpentine (74) and a rosin-derived amine for degelling oleoresin varnishes. (101) Patents have been granted covering methods of preparing new and improved metal resinates from rosin and rosin derivatives (79).

f. Rubber. It is believed that, in the event of another outbreak of war, this country would be faced with an acute rubber shortage. Work has progressed on growing rubber in the United States, and guayule rubber, which is in every respect the equal of Malayan plantation rubber, has now been produced. (125)

g. Sorghum Grain Starch. Recent studies have shown that sorghum grain starch has characteristics similar to those possessed by nonglutinous root starches. The Kafir starches of intermediate character give firm, clear, workable gels and are therefore good for edible purposes. (108)
E. Miscellaneous Materials

1. Chemicals

   a. Alcohol. Grain alcohol can be made from wood waste at less than one-half the price of production from black strap molasses. In the process, sawdust and wood chips are treated by continuous percolation with dilute sulfuric acid. The product of this process can be used without concentration for cattle food and for the production of grain alcohol. (6)

   b. Aldehydes. Several aldehydes have been obtained from lignin of the Australian eucalyptus. It was found that vanillin, syringaldehyde, and a third methoxyl-free aldehyde were obtained from nitrobenzene oxidation of eucalyptus woods. The methoxyl-free aldehyde was identified as p-hydroxybenzaldehyde after chromatographic purification. (7)

   c. Dyes. Dyes have been made from citrus fruit rinds by the University of Florida Agricultural Experiment Station. The dyes are water-soluble and are limited to wool and silk; they are also being adapted for a type of wood stain. These are azo dyes, produced by using the bitter glucosides extracted from the peels as intermediates. The dyes appear best in yellow-red colors which are bright and quite pleasing. (23)

   An Indian plant has been built which uses teakwood as a raw material for dyes (42).

   d. Glycerine. Glycerine was reported short in the latter part of this year. A German chemist has developed a new substitute for glycerine, called "Kurozin." The composition has not been revealed, but it is reported that all of the materials needed for its manufacture are available in Germany. (39)
e. Starch. A new type of starch called "Amioca" is now being marketed. It comes from "waxy" corn and has properties similar to those of tapioca. A sponge for surgical use has been developed from corn starch. It has proved to be an excellent hemostatic agent and is now being clinically tested at a number of hospitals. Another useful product has been obtained by treating starch with allyl chloride. This product can be dissolved in an organic solvent and sprayed on wood, glass, or metal like any lacquer. It shows promise as a furniture coating.

f. Sugar. Dextran, a troublesome slime in sugar mills, may become an important blood plasma substitute. Inositol, sorbitol, and galactinol have been isolated from sugar cane and beet juice.

g. Synthetics. Extensive research has shown that materials for making acetate rayon and certain plastics can be produced satisfactorily from eucalyptus pulp.

h. Vanillin. A new plant to produce vanillin from wood lignin has been placed in operation at Seattle, Washington. This is being done in an attempt to overcome a ten-year shortage of vanillin.

2. Foods, Spices, and Flavorings

Rice, a staple food for much of the world's population, has been extremely short on the world market this year. Black pepper has also been reported short on markets in this country.

a. Animal Feed from Waste Materials. An animal feed product has been developed from waste from tomato-processing plants. The process is said to convert 83 per cent of the waste to a feed rich in protein and
fat. The cost of conversion will probably be greater than the sale value of the feed, but it is the cheapest way to dispose of the waste safely. (32) A process has been mentioned to obtain feed-grade molasses from fruit cannery waste (26). A synthetic milk for feeding calves has been developed from technical fat from slaughter houses (72).

b. Corn cob uses. In addition to being a furfural raw material, corncobs are now being used to polish and burnish cartridge cases, as soft grits in air-blasting airplane engines, and as a grit in the metal-stamping and electroplating industry. The ground cobs are used as a milk by gardeners and nurserymen. The ground cobs can also be combined with molasses and other nutrients to form a feed for beef cattle. (27)

3. Insecticides

During 1952 all insecticides except pyrethrum seemed to be in good supply.

It has been found that a combination of two weak insecticides will kill just as well as one strong one. The amount of each insecticide necessary can be determined mathematically. (83)

Systox is a new insecticide developed to control aphids and mites on cotton. It is an organo-phosphate ester and can be sprayed on the seed or foliage or put in fertilizer or irrigation water. It is absorbed by the plant and renders the foliage and plant juice toxic to insects. (75)

The plant Heliopsis longipes, known to occur only in Mexico, yields an insecticide as toxic as pyrethrins to houseflies. The active principle of this plant is N-isobutyl-2,6,8, decatrienamide; it is closely related to scabrin. (68)
4. Tannins

Tannins from the bark of Ponderosa pine and Douglas fir compare favorably with quebracho tannin for many major industrial uses such as in leather manufacturing and for the viscosity control of oil-well drilling muds (70).

A tanning material containing an extractive of canaigre is now being tested (22). Lignin has also been mentioned as a source of tannins (48).
V. CONCLUSIONS AND RECOMMENDATIONS

After reviewing the results of this survey, it is believed that the procedure used in the literature investigation has been satisfactory for obtaining the information desired. The survey has indicated that there are definite needs for domestically grown raw materials to supplement imports from sources of supply which may not be available to this country at all times. While most materials have been in good supply during 1952, there have been definite shortages, largely caused by the breakdown of trade with some regions.

One of the most obvious needs is a source of drying oils, particularly those of the tung oil type. Several possible new oils have been mentioned which show promise of being satisfactory tung oil substitutes. There is also a need for a domestic source of lauric acid oils such as coconut and palm oils. Many of the essential oils were also short during this year.

Fibers were found to be in good supply this year, but many of our fibers are imported, chiefly from the Far East. A new source of wood for paper making would be desirable to supplement current supplies.

There were shortages of many botanical drug materials, many of which are imported from the far reaches of the world.

A wax which is not subject to international manipulation and which can take the place of carnauba is definitely needed. Many water-soluble gums and vegetable resins would no longer be available to us in time of war.

A domestic source of an insecticide like pyrethrum is desirable, and new sources of tannin could be used to great advantage.
Many chemicals are needed in greater supply, especially the alcohols and glycerine.

Notable in the literature were reports of the widespread development of synthetic materials designed to take the place of many botanical raw materials.

The information obtained in this survey demonstrates how much the United States depends on foreign sources of supply for many vital plant raw materials. A continuous survey of current literature could reveal shortages as they develop and might (in some cases) supply the information necessary to relieve these shortages; it would give the Department of Agriculture an up-to-date basis for planning the introduction and development of new plants. Present world conditions, with their abnormal trade relations, make up-to-date information doubly important.

Respectfully submitted,

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VI. APPENDIX
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PHASE REPORT NO. 2
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SURVEY OF THE NEEDS OF INDUSTRY FOR RAW MATERIALS FROM NEW PLANTS TO BE GROWN IN THE UNITED STATES

By

T. A. WASTLER, JR.

CONTRACT NO. A-1S-33685

DIVISION OF PLANT EXPLORATION AND INTRODUCTION
BUREAU OF PLANT INDUSTRY
UNITED STATES DEPARTMENT OF AGRICULTURE

MARCH 1, 1953
ENGINEERING EXPERIMENT STATION
of the Georgia Institute of Technology
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I. SUMMARY

Two bulletins, each concerned with recent developments in plant-derived industrial raw materials, were published as an outgrowth of the survey of current literature as discussed in Phase Report No. 1, Contract No. A-1S-33685, and were distributed to individuals and organizations interested in these types of materials. One bulletin deals with fixed vegetable fats and oils; the other is concerned with vegetable waxes, gums, and resins. These bulletins comprise the Appendix of this report.

To obtain the information presented in these bulletins, a careful, continuous, page-by-page scanning of trade literature was conducted; the pertinent articles were abstracted. Eighteen selected journals were surveyed, and several standard indexes were also examined.

Included in the bulletins is information of economic or technological importance published in the literature surveyed. Recent economic and technological developments are discussed, as are reported shortages and new sources of raw material. Price trends and volumes consumed or produced are presented in graphical form for some commodities.

The comments received indicate that the bulletins were well-received by interested persons as useful summaries of recent developments in their respective fields.
II. INTRODUCTION

A review of the literature was undertaken as a part of the program initiated at Georgia Institute of Technology by C. O. Erlanson, Head of the Division of Plant Exploration and Introduction, Bureau of Plant Industry, Soils and Agricultural Engineering, United States Department of Agriculture, to determine the needs of industry for plant-derived raw materials and to locate published information indicating new crops that might have economic value. As an outgrowth of this survey, two bulletins, each dealing with recent developments in a different raw material field, were published and distributed to interested individuals and concerns.

III. PROCEDURE

During the survey of current literature as described in Phase Report No. 1, Contract No. A-1S-33685, articles dealing with fixed vegetable fats and oils and vegetable waxes, gums, and resins were abstracted placing particular importance on recent technological and economic developments, in addition to the information concerning shortages and new material sources.

Several standard indexes were also examined under pertinent headings for further information. The periodicals surveyed are listed in the bibliographies of the bulletins, which comprise the Appendix of this report.

The information so obtained was correlated and checked for accuracy insofar as possible. Weekly price figures were obtained from the market sections of the Oil, Paint and Drug Reporter and the American Paint Journal; monthly import figures were obtained from the United States
Department of Commerce Report FT-110, United States Imports of Merchandise for Consumption; and monthly domestic production figures for naval stores were obtained from Bureau of Agricultural Economics figures as reported in the Naval Stores Review. Graphs were prepared from these data to be included wherever appropriate in each bulletin.

Two bulletins were published under the following titles:


Upon publication, copies of each bulletin were distributed as shown in Table I. Those copies sent to the Bureau of Plant Industry, Soils, and Agricultural Engineering were to be distributed to their mailing list or retained for the use of the Bureau; copies retained by Project No. 177-170, Engineering Experiment Station, Georgia Institute of Technology, were distributed to industrial concerns interested in the appropriate fields or kept for use on the Project; copies retained by the Technical Information Services of this Station were distributed to libraries and research institutes (some in other countries) or were held for distribution to persons requesting copies. Numerous requests were received, and copies were distributed accordingly.
Phase Report No. 2, Project No. 177-170

TABLE I

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IV. DISCUSSION OF RESULTS

The bulletins published included the information of economic or technological importance which was found in the literature published during the period covered by the survey. When the information was available, graphs of price trends and volumes consumed, imported, or produced (whichever was applicable) have been presented for each commodity considered, together with comments about any significant development affecting the economic position of these materials. Reported scarcities and the probable reasons for their existence were mentioned. New developments, possible new raw materials and new products were discussed, and any recent technological developments which might affect the position of any of these materials were included. Opinions on the supply and price trends to be expected in the future, as well as reported estimates of future production, were also presented whenever they were available.

Many comments were received concerning both bulletins. These were generally favorable, and it is believed that many persons found the bulletins valuable digests of current information concerning fats and oils, and waxes, gums, and resins. Some copies are being held by the Engineering Experiment Station for future distribution as requests are received.
V. CONCLUSIONS AND RECOMMENDATIONS

The bulletins described in this report were digests of published information concerning recent developments in the fields of fixed vegetable fats and oils, and vegetable waxes, gums, and resins.

The procedure used was, in general, satisfactory for obtaining the desired information, and it is believed that the same procedure could be used to advantage in future surveys of this type. The technique of page-by-page scanning, while somewhat tedious, seems to be the only method suitable for obtaining such diverse and detailed information. Abstract journals are quite useful in obtaining technological information from obscure journals which would not repay the time spent in page-by-page scanning.

The comments received indicate that the bulletins were well-received and that they proved to be valuable digests of current developments in the fields of fixed vegetable fats and oils, and waxes, gums, and resins. If published on a periodical basis, such material would probably be valuable to industry and to many interested persons.

Herschel H. Cudd, Acting Director
Engineering Experiment Station
VI. APPENDIX

Bulletin No. 13
Bulletin No. 15
Industrial Raw Materials of Plant Origin

I. Recent Developments in
Fixed Vegetable Fats and Oils

T. A. WASTLER
P. M. DAUGHERTY
H. H. SINEATH

BULLETIN NO. 13

ATLANTA, GEORGIA
1952
FOREWORD

This bulletin introduces a series of publications about industrial raw materials from plant sources; it discusses the economic and technological developments in the field of fixed vegetable fats and oils between January 1 and July 31, 1952.

Many of those actively interested in this subject do not have the opportunity to read and assimilate the pertinent but scattered literature. A survey of this current literature is compiled here and is presented so that, with a minimum expenditure of time and effort, a person interested in recent occurrences in the field can obtain an over-all view of the entire industry and of developments concerning any specific oil of commercial importance (or of possible future importance). The information is as complete as possible, although excessive details are omitted. The opinions expressed here are those of the editors of the journals surveyed unless otherwise noted, and those sections discussing new developments include complete references for readers who desire additional information.

The authors and the sponsoring organization hope to determine whether or not a periodical summary of this subject proves valuable to those concerned with fixed vegetable fats and oils. Comments on the value and utility of continuing this bulletin will be appreciated.

This survey has been made possible by the Division of Plant Exploration and Introduction, Bureau of Plant Industry, Soils and Agricultural Engineering, United States Department of Agriculture under the Research and Marketing Act of 1946. It was conducted at the State Engineering Experiment Station, Georgia Institute of Technology, Atlanta, Georgia. The survey is part of a larger program, initiated by C. O. Erlanson, Head of the Division of Plant Exploration and Introduction, to investigate the needs of industry for plant-derived raw materials and to conduct market surveys for various commodities worthy of possible future development. The authors are grateful to those libraries, industrial organizations, and individuals who have cooperated in this program.

Atlanta, Georgia
August 6, 1952

T. A. Wastler, Jr.,
Research Assistant

P. M. Daugherty,
Research Assistant

H. H. Sineath,
Research Engineer
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Unless otherwise noted, the market statistics contained in this report were obtained from the market sections of the journals surveyed.
SCOPE OF THE SURVEY

This survey includes the information of economic or technological importance which was found in the literature published during the period covered. When the information has been available, graphs of price trends and volumes consumed have been presented for each oil and fat, together with comments about any significant developments affecting the economic position of any of these commodities. Reported scarcities and the probable reasons for their existence are mentioned. New developments, possible new raw materials and new products are discussed, and any recent technological developments which may affect the position of any oil or fat are included. Opinions on the supply and price trends to be expected in the near future, as well as reported estimates of future production, are also presented.

To obtain the information given in this bulletin, a careful, continuous page-by-page scanning of trade literature was conducted; the pertinent articles were abstracted. Eighteen selected journals were surveyed; these are listed in the Appendix. Reports of the United States Department of Commerce have been freely used, and some reports and bulletins published by various experiment stations were consulted. Several standard periodical indexes were examined under pertinent headings; these are also listed in the Appendix.
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I. GENERAL SUMMARY OF DEVELOPMENTS

Heavy inventories of fats and oils, built up in late 1950 and early 1951, appreciably affected business during the major portion of 1951. Consuming demand began to recede in the late Spring, and it continued light and spotty during the balance of the year as consumers limited purchases. For example, in December, 1951, the paint industry used 37,801,000 pounds of vegetable oils, compared with 45,890,000 pounds in December, 1950. Consumption of most of the individual oils declined, with the greatest drop in that of tung oil (down almost 50 per cent). Several oils, however, were used in larger quantities in December, 1951. These included coticica oil and vegetable oil fatty acids, obviously because of their relatively lower prices. This situation brought about a gradual decline in prices, which in many instances reached its lowest levels at the end of the year.

The year 1952 opened with a slight increase in export demand which soon died away. Business was very slack during the first four months of 1952, but in May increased consuming demand caused an upswing in business and prices. Domestic consumption and exports are expected to continue at a high level during the remainder of 1952 as the supplies built up in 1950 and 1951 are depleted.

The world's 1951 production of the principal fats, oils, and oilseeds—all in terms of fats and oils—is estimated at a record 25,850,000 tons, according to the Office of Foreign Agricultural Relations. This is an increase of eight per cent from 1950. For the first time since the war the output of fats and oils was sufficient to restore the per capita supply to approximately the prewar level.

The United States is now the largest single source of surplus fats and oils, exports of soybean and cottonseed oils being especially important. This country contributes to the production of six widely used oilseed crops, and very heavily to three of them—cottonseed, soybean, and flaxseed. In recent years three others—peanut, tung, and olive—have become increasingly important. This year for the first time the United States will produce a significant quantity of a seventh oil crop—castor beans. Domestic production of oils and fats in the year beginning October 1, 1951, probably will total over 12.5 billion pounds. Total output includes the oil-equivalent of domestic oilseeds exported for crushing. Increases in cottonseed oil and lard will more than offset drops in butter and soybean, peanut, and linseed oils. Domestic disappearance and exports are expected to continue at a high level, but stocks of food fats in October 1, 1952, probably will be larger than on the same date a year earlier.

The future production or price of certain oils may be affected by several new technological developments recently announced. Perhaps the two most significant are a method of obtaining coconut oil from fresh coconuts without preparing copra first and a new type of solvent extraction process for cottonseed, soybean, rice bran, and possibly some other oils.
II. DRYING OILS

Dehydrated Castor Oil
(See Castor Oil.)

Linseed Oil—Figure 1 (A), Figure 2 (D)

Late in January the price of linseed oil rose slightly as the result of improving export demand and the increasing cost of seed. In this month the Commodity Credit Corporation offered for domestic sale five million bushels of flaxseed and 212 million pounds of raw linseed oil; a sharp break in the price of oil occurred during the next two weeks as the price of flaxseed declined. This was partially because of progress in the Korean truce negotiations, according to some sources. The oil price rallied slightly, then continued its downward trend as the price of flaxseed went lower. The decline was aided by the financial panic in India during March.

Effective March 31, the Office of Price Stabilization raised the price ceilings on linseed meal products $5.50 per ton. Further price declines, however, were aided by a lack of demand, a surplus of oil, heavy importation volumes, and the international conditions already mentioned. In late April prices began to rally and soon reached a stable level which has generally continued.

World linseed oil production was below prewar in 1951. The smaller output was explained mainly by a sharp reduction in Argentina’s flaxseed crop and by a substantial reduction in United States production.

Quantities of linseed oil for export from Argentina will be relatively small throughout 1952, according to the Bureau of Agricultural Relations. Surpluses previously existing for both flaxseed and oil were liquidated by large shipments in 1951. The crop harvested at the first of this year was the smallest since Argentina became a major producer, insufficient even to keep the domestic crushers operating. Maximum exports this year are forecast at 110,000 short tons of linseed oil and possibly 790,000 bushels of flaxseed, compared with 286,000 tons and 7,183,000 bushels respectively, in 1951. Argentina has raised the basic price for the 1952-53 flaxseed crop 30 per cent over that which applied to the 1951-52 crop. Since the Argentine announcement provided also for increases in the basic prices for wheat and other grains amounting to 45 to 50 per cent over last year’s, it would appear that flaxseed will be placed at a competitive disadvantage in the interest of expanding grain production.

India’s crop is indicated roughly at around 15,000,000 bushels or about the same as last year’s.

With a drop in demand and the consequent decline in flaxseed prices, the Uruguayan oilseed industry shut down in mid-March with no indication of reopening plans, this in spite of the fact that Uruguay’s 1951-52 flaxseed crop was 26 per cent greater than last year’s.
The 1952 flaxseed production goal for the United States was set at 38 million bushels, compared with 1951 production of 33.8 million bushels. Farmers' intentions to plant flaxseed in 1952 were reported at somewhat less than last year's acreage. The indicated flaxseed production from the acreage planted was put at 28,328,000 bushels.

The United States Department of Agriculture felt that the flaxseed crop goal would be sufficient in 1952, because the estimated domestic disappearance plus exports for the crop year 1952-53 should not exceed 750 million pounds of linseed oil, equivalent to about 37.5 million bushels of flaxseed.

Since the domestic production goal was not reached, it is apparent that some importations will be necessary. However, there is a tendency for many consumers to try to replace linseed oil with cheaper oils in some formulations. This tendency, combined with good domestic production (in spite of poor weather in the early part of the season), should keep required imports at a fairly low level.

Oiticica Oil--Figure 1 (B), Figure 2 (F)

Oiticica oil, as well as others of the cheaper drying oils, is largely used in the place of tung oil. This was very evident during the period covered by this survey. The price of oiticica held fairly steady at first, but soon moved upward in sympathy with tung. As tung began to price itself out of the market, oiticica remained steady. By April the prices of competitive oils, especially linseed, had fallen to such an extent that some reductions in the price of oiticica were necessary. The market stabilized itself and prices became steady at a somewhat lower level.

Consumption of oiticica oil was fairly high in the first half of 1952. This was, of course, due to the unfavorable supply and price situation of tung oil. This trend can be expected to continue as long as the present trade restrictions with China last, unless there is a very large increase in production of tung or oiticica in the Western Hemisphere.

The Brazilian production of oiticica oil in 1951 has been reported at 27,600 tons, or only 70 per cent of the 40,800 tons in 1950. The 1952 crop is estimated at 18,700 tons. Reduced yields are attributed to drought during the past two years. It appears that there may be a definite shortage of oiticica during the next year, especially if the current trend toward using oiticica and other cheaper oils in place of tung continues.

Soybean Oil--Figure 1 (C), Figure 2 (C)

The United States exported a record volume of soybeans and soybean oil in the calendar year of 1951. Shipments in soybean equivalent amounted to 76.9 million bushels, equal to over one-fourth of the record production in 1950. The actual shipments consisted of 24.6 million bushels
of beans and the remainder in oil. The largest single volume of soybeans, 11.8 million bushels, went to Japan. The bulk of the oil, 84 per cent, was exported to Europe with Spain the largest purchaser because of the failure of the olive crop in that country. Japan, unable to obtain soybeans from Manchuria, was forced to purchase from this country.

At the beginning of 1952 improved export demand created a firm tone temporarily. However, soybean crushers maintained that they could not pay the current price for beans, sell the meal and oil at the market price, and make a profit; therefore, supplies were light. Throughout the remainder of January prices of soybean oil worked lower, along with the prices of competitive fats and oils, largely because of diminishing export demand. During February the increasing cost of soybeans stiffened soybean oil. The latter part of the month and succeeding weeks saw the prices of soybeans and oil gradually decline with those of competing oils. The financial panic in India aided this decline, as did rumors of peace in Korea and strikes in the United States. When the OPS suspended price controls on soybean oil in the latter part of April, prices took a slight jump, partly as a result of this and partly as a general reaction to the declining prices of the previous weeks. A higher price ceiling for soybean meal was announced, but crushers held that it still wasn't enough to make production profitable, and some large producers closed down. Action was initiated against the OPS on the grounds that an illegal price ceiling for soybean oil had been established. Improved consuming demand, coupled with the shutdowns previously mentioned, kept the price of soybean oil rising. Late in June decreased consuming interest caused slight decreases in most oils.

World production of soybeans in 1951 was estimated at 658,900,000 bushels by the Office of Foreign Agricultural Relations. This is only slightly less than the record 1950 crop. The decline is primarily due to decreased production in the United States from an all-time high of 299,300,000 bushels to 280,500,000 bushels.

During the first seven months of 1952 the domestic consumption of soybean oil gradually rose. This was due largely to the favorable price condition of soybean oil as compared with other oils of the same type. Many consumers were making a distinct effort to incorporate soybean oil in formulations wherever possible. Exports were down slightly at the first of the year, and exceptional exports are not expected for this year.

The 1952 soybean goal was set at 276 million bushels by the USDA, compared with the 1951 total production of 278 million bushels. Farmers' intentions to plant soybeans were given at 15,457,000 acres in 1952, compared with 14,838,000 acres last year. In the state of Georgia, the acreage of soybeans grown for the oil has increased by more than 10,000 acres. The development of varieties adapted to the area and the fact that oil mills now furnish a ready market are largely responsible for these increases. Actual output of oil is expected to drop over the summer as the result of seasonal influences.
Plantings of soybeans in Brazil were delayed because of poor weather, but good crops are still expected. Soybean production as an export crop is on the increase in Turkey, but volumes are not expected to get very large. The Bolivian government is fostering the development of a domestic vegetable oil industry, and widespread import restrictions have been imposed. A record olive oil output in Italy will probably result in decreased imports of fats and oil this year.

It is predicted that domestic production of soybean oil this year will approach the levels of 1951. However, the unfavorable price ratios now existing may limit crushing somewhat.

In the distant future the development of new varieties of soybeans may extend the growing of this crop to submarginal areas; at the same time these new varieties may increase the yield per acre considerably. One trade source has predicted 500-million-bushel domestic crops of soybeans in the not too far distant future.

New Variety of Soybeans

Development of a new variety of soybean, called Perry, has been announced as a full-season variety for southern Indiana, southern Illinois, central and southern Missouri, and eastern Kansas. It is reputedly a high-yielding type, and the beans are of high oil content. All seed from the 1951 crop has been allotted to seed producers for increase, so there will be plenty of seed for planting in the 1953 season. (CD, 3-52, p. 17)

Soybean Oil Stabilizer

Phytic acid, an ingredient of many grain seeds, is a good stabilizer in preventing off-flavors in soybean oil. As little as half a pound of phytic acid added to one ton of soybean oil will lengthen the storage life of the oil by preventing the development of off-flavors. Phytic acid is the hexaphosphoric derivative of inositol and occurs in nature as the calcium salt. (CD, 1-52, p. 18)

New Method of Measuring Oil in Soybeans

A high-frequency oscillator can measure the oil in a solution of standard solvent in 15 minutes, as compared with the several hours required in the present method. The soybeans are first ground with the solvent in a special grinder-extractor. After filtering, the solvent-oil mixture is placed in the cell of an electric oscillator which measures the dielectric constant. The reading is then converted to percent oil with a table prepared by analyzing many samples by the old method. Two analysts can make 20-30 determinations per hour. The estimated cost of equipment, if used at capacity, is claimed to be about one-half that of the equipment needed for testing by methods now in use. (OP&DR, 7-14-52, p. 286)
Tung Oil--Figure 1 (D), Figure 2 (L)

Tung oil occupies a unique position among the drying oils at the present. This position results from the disruntion of our trade with Communist China, which produces the bulk of the world supply. Since our own production of tung oil was finished for the year during this period, the Argentine has a corner of the world supply from which this country can draw, and the Argentine has consistently refused to sell at a price below 39.75 cents per pound in New York.

At the beginning of 1952 tung oil prices increased under the influence of active demand and limited offerings. It was announced that price support would be available to tung nut producers (for the 1951 crop) by means of the usual purchase agreements and loans at the rate of 26.5 cents per pound of oil. By the first week in March this oil had priced itself out of the market, and consumers had begun to use the cheaper drying oils. The price of tung began to decline. The decline continued until a considerably lower price was reached in April. The price was maintained and then increased slightly, although other drying oils continued to decline slightly. Tung oil prices rose a fraction at the beginning of May when the British announced that they were also leaving China, dimming any faint hope that trade with China might be resumed at any time in the near future. In June tung declined slightly because of heavy shipments from Argentina.

Tung oil for a number of months has been coming into the United States in smaller volume owing to the fact that imports from China were cut off by the embargo imposed in December, 1950. The result has been an increase in the relative importance of Argentina as a supplier; it occupied first place in 1951. Imports of tung oil in 1951 totalled only 14,853 short tons, a sharp decline from the 56,242 ton arrivals in 1950 and only 25 per cent as large as prewar. Imports from China dropped from 44,114 tons in 1950 to 5,590 tons in 1951. Arrivals from Argentina were somewhat less than in the previous two years, but still made up almost one-half of the total 1951 importation. Smaller quantities were received from Brazil, Paraguay, and Hong Kong. The few imports received from China apparently consisted of quantities in the process of being shipped prior to the embargo.

Domestic tung production now centers around the coastal area of Louisiana and Mississippi with some production in East Texas. As a result of last year's weather in this section, the total domestic tung oil production from the 1951 crop is expected to be considerably less than the 18 to 21 million pounds predicted earlier. Reports shortly after the first of the year (1952) indicated that the oil content of the crop is running from two to three per cent less than expected because of cold damage the previous winter and a late summer drought.

The tung crop situation in Paraguay and Argentina was reported as being very discouraging. While Paraguay produced between 2,000 and 2,500 tons of oil last year, this year's crop may not exceed 1,000 tons and will definitely be less than 1,500 tons. The Argentine crop suffered from heavy frosts and high winds, and good production is not expected.
The USDA estimates the tung oil situation for 1952 as follows: the total supply will be 59 million pounds, of which 15 million pounds is expected from imports, 25 million pounds from domestic production, and 19 million pounds carryover from 1951 stocks. The American Paint Journal has estimated that there will be a 5.4 million pound deficit at the end of 1952.

A severe shortage of tung has been predicted for this summer because of the breakdown of trade between Hong Kong and China. It is felt that this will cut off the main European supplies of tung oil and that European buyers will have to turn to the Western Hemisphere for any tung oil supplies they get. The situation here may not become critical, however, in view of the declining use of tung oil in favor of processed linseed oil, oiticica oil, and dehydrated castor oil.

III. OTHER OILS

Babassu Oil—Figure 1 (E), Figure 2 (E)

Babassu oil generally followed the trends of coconut oil and copra. The 1950-51 babassu crop in Brazil (September-March harvest) is estimated at 71,650 tons. Estimates of the last season's harvest are not yet available. The discontinuance of barter trade in babassu oil in early 1951 and falling world prices have created uncertainty regarding the export market.

Castor Oil—Figure 1 (F), Figure 2 (K)

At the beginning of 1952 a serious deficiency of dehydrated castor oil was reported. High prices of the normally used drying oils caused many consumers to consider using dehydrated castor or other oils, such as soybean, in their place at the first of the year. Late in January the supply situation became easier, but prices remained high until consumer resistance caused declines in prices of drying oils. Prices gradually declined throughout March in sympathy with a decline in crude castor oil until a stable condition was reached.

About 350 million pounds of castor beans are needed annually in the United States; most of this comes from Brazil, 80 per cent of the crop in that country being shipped to this country. About one-fourth of the total world production is consumed by the United States, and of this about 30 million pounds are converted to dehydrated castor oil.

Crude castor prices were stable until early March when a financial and economic situation in India caused the price of Brazilian oil to decline sharply; then the prices of all grades of domestically crushed oil declined in the United States as a reflection of Brazilian conditions. The prices rallied later but remained at a lower level than they had reached previously. In the first part of April prices dropped off again as a result of an excess of oil, poor demand, and heavy importations. During this month there were also rumors of peace in Korea; this was probably the reason for declining prices in the latter part of the month.
After the long series of declines, prices finally reacted slightly and became steadier.

The United States imported 44,586 tons of castor oil in 1951 to set a new high record for this commodity. On the other hand, castor bean purchases of 74,558 tons were the smallest since 1938. Total arrivals in bean equivalent amounted to 171,638 tons against 183,616 tons in 1950. Record imports of castor oil, mostly from Brazil, were attributed to national stockpiling and to the high level of industrial activity in the United States. Imports of the oil were relatively larger than those of the bean owing to Brazil's efforts to export more castor in the form of oil.

The Indian government imposed sharp export-quota restrictions on castor beans and oil in January for the January-June licensing period. Oil exports were reduced to 15 per cent of exports for the best year from 1948-51, and bean quotas were reduced correspondingly. The government is steadily implementing its declared policy of promoting oil exports in preference to oilseeds by allowing export quotas of castor oil instead of castor beans. The order has caused some dissatisfaction in Indian trade circles.

The United States Department of Agriculture announced March 13 that no limit has been placed on the total quantity of medicinal castor oil which may be licensed for export during the period April-June. Export allocations of 100,000 pounds of commercial and sulfonated castor oil were announced also. These were the same as were allocated for the first quarter of 1952.

In May castor bean stocks were reported to be low in all parts of Brazil, and mills in some sections were reported as having difficulty in obtaining sufficient seed to maintain operations.

Castor oil imports, although lower in January than in the preceding months, remained unchanged for the seven-month period ending in January as compared with the corresponding seven-month period of the preceding year. In February castor beans and oil were being offered in increasing quantity by crushers in India, Europe, and South America. However, consumer interest had quieted down in many cases.

Output of castor oil from last year's domestic bean crop will amount to less than 9 million pounds instead of the 20 to 30 million pounds of oil originally expected. Primarily because of extremely adverse weather conditions, and also excessive shattering and capsule drop near the end of the season, the crop was far below expectations. Data indicate that only 75 per cent of the planted acreage was harvested, and many stands in Texas and Oklahoma would not have been harvested at all except for the failure of other crops in the same area. Returns for the 1951 crop of castor beans were unfavorable compared to other crops, such as cotton or peanuts. In many instances, however, the only farm income in some areas was from castor beans, as they withstood the unfavorable weather better than most other crops.
In recent years, domestic production of castor beans has been increasing, and in 1952 it is predicted that about one-seventh of the United States requirements will be furnished by farms in California, Arizona, Texas, Oklahoma, and neighboring states. Development of domestic supplies has been greatly dependent upon the successful breeding of varieties suitable to North American economic and edaphic conditions. Considerable progress in this direction has been made by the United States Department of Agriculture. This Agency has a program instigated to encourage the production of castor beans in this country. For this year it is contemplated that castor beans will be produced under the program on about 200,000 acres in areas for which adapted seed is available within the states of Arizona, Arkansas, California, Oklahoma, and Texas. The program will be available to producers who enter contracts with the Commodity Credit Corporation or with organizations or persons who contract with the CCC to arrange for castor bean production in specified areas within such states. Premiums will be paid for certain improved varieties or strains of castor beans grown for planting seed under special seed production and purchase contracts. Technical guidance is available to producers participating in the program.

Early this year, at the request of the Munitions Board, the CCC undertook a program intended to develop a domestic supply of 34 million pounds of castor oil. This program contemplated plantings of 76,000 acres of castor, 75 per cent of which was allocated to Texas and Oklahoma. It was estimated that these plantings would yield about 40,000 tons of castor seed and about 34 million pounds of oil, or about one-third of the normal consumption of this oil.

Estimates of Brazil's castor bean crop this year point to an even greater harvest than the 193,000 ton yield in 1951. Extensive plantings of castor beans were completed, and a large crop is expected from the August harvest. The intermediate crop in Bahia is expected to be small. Prices of castor beans have been favorable, and, if the weather is good, production should increase considerably over that of the past two years.

The official estimate of India's 1951-52 castor bean production has been placed at 116,500 short tons. Current output is at the same level as the 1950-51 crop, although acreage was up slightly this year. Trade sources believe India has an exportable surplus of 56,000 tons of castor beans. To conserve the oilseed in the country and, at the same time, to utilize the crushing capacity already established, the Indian government will continue to encourage the export of castor oil rather than castor beans.

Because of the current situation in China, the use of tung oil is declining, with increasing substitutes among other drying oils, including dehydrated castor. If crops are of the magnitude expected, prices should remain steady at somewhere near their present levels.

The long-term trend in domestic consumption of castor oil has been upward and is likely to continue so in the future. Whether or not domestic castor beans can compete on the open market with imported beans
is still to be determined; it is also still to be determined whether castor can compete effectively with other crops.

**Castor Oil Substitute**

A substitute for castor oil has been developed by Spencer Kellog and Sons. Known as "Kelcastol," it has many of the properties of ordinary castor oil, being non-drying and of a light color. It is a modified vegetable oil (but not based on castor oil) and will be cheaper than castor oil. (CD, 2-52, p. 16)

**New Use for Castor Oil**

Castor oil is used as the plasticizer in a new lightweight material consisting of a nitro-cellulose-based compound on cotton sheeting. It has certain advantages over ordinary oilcloth. The material is washable, stain and ink resistant, and waterproof. (C&EN 7-14-52, p. 2918)

**Coconut Oil and Copra—Figure 1 (G), 1 (H), Figure 2 (A)**

The prices of both crude and refined coconut oil followed the trends of copra fairly closely. In late January the appearance of resale coconut oil in the market caused decreases which were maintained until the second week in February, when a scarcity in offerings of copra caused the prices to rally slightly. During the early part of March a decrease in prices of soybeans and soybean oil caused a general decrease in most edible oils; there was a sharp break in the price of copra at this time, and coconut oil fell accordingly. The following week, copra rallied somewhat, carrying coconut oil slightly higher. A financial and economic panic in India in the middle of March caused a general decline in prices which continued until the first week in April, when there was a reaction from the decline and prices began to rise.

At this time, also, copra slab cake, copra oil meal, and copra pellets were exempted from price controls by the OPS. Since all copra processed in this country is imported, domestic crushers must purchase copra on the world market in competition with processors who are not limited by what they can charge for oil and meal.

In the latter part of April liquidation of futures of cottonseed and other oils caused general price declines. Early in May gradually improving consumer demand began to affect prices, and there were general advances in most commodities. This, coupled with increasing export demand from Europe, kept the price of coconut oil and copra rising.

In the first week of June a bill was passed by Congress providing that coconut oil produced from copra grown in the trust territory of the Pacific Islands would be exempt from the two cents per pound processing tax. The basic processing tax of three cents per pound would still apply.
In the latter part of June the slackening buying interest and the appearance of resale oil caused further decreases. Then a shipping strike on the Pacific coast stiffened the market.

United States copra and coconut oil imports in 1951 amounted to 449,483 and 56,367 short tons, respectively, according to OFAR. This is seven per cent less than the combined arrivals in 1950, and only seven per cent above prewar. Although copra imports in 1951 were almost double those of prewar, coconut oil imports amounted to only one-third of the 1935-39 average. All of the copra and all but 31 tons of the coconut oil imported came from the Philippines because of trade agreements with that country.

Philippine exports of copra and coconut oil in 1951 were up about 10 per cent above the 1950 total of 801,958 tons of copra equivalent. In January, 1952, exports of copra and coconut oil were 1½ per cent higher than they were in January, 1951. However, exports in the period January-March, 1952, were two per cent less than exports for the same period in 1951. The United States continued as the largest buyer, but the United States proportion dropped from 60 per cent last year to 44 per cent for the corresponding period this year. European shipments increased from approximately 28 per cent to 35 per cent. The reductions in the amounts of copra and coconut oil imported to the United States in recent periods were due to weakened market demand, with consequent lower prices.

Exports of both crude and refined coconut oil from the United States in 1951, in terms of crude oil, totalled 20,103 tons, against 12,470 tons in 1950. The increase of 61 per cent over 1950 occurred entirely in the crude oil exports of 16,369 tons. Refined oil exports of 3,523 tons were only two-thirds of the 1950 tonnage. North American countries received about 60 per cent of the 1951 crude oil shipments, with Cuba taking the largest quantity. Venezuela took about half the exports to South America, while almost all the European shipments went to Germany. The decrease in refined oil shipments in 1951 was accounted for principally by the decreased volume going to Venezuela.

The United States Department of Agriculture announced March 13 that coconut oil has been removed from export allocation and that the Office of International Trade is being authorized to place these oils under general license.

India's Ministry of Finance, late in January, announced reductions in customs duties on imported coconut oil. The Indian press stated that imports of coconut oil from Ceylon and Singapore, the principal suppliers to India, have declined over the past year. As the reductions are expected to reflect themselves in lower prices on the supplying markets, they should also be a factor in increasing imports of coconut oil into India. Ceylon coconut oil exports were 4½ per cent higher than in the previous year, while exports of copra, desiccated coconut, and fresh
nutes decreased 9, 11, and 23 per cent, respectively. Copra production in the Federation of Malaya during 1951 is estimated at 171,000 tong tons, or 21,500 tons above the 1950 output. In addition to the domestic output, Malaya imported 100,898 tons of copra in 1951, principally from Indonesia.

The USDA has predicted that there will be substantial carryover stocks of fats and oils at the end of the current crop year, September 30. However, weakened demand for coconut oil is likely as a result of the increased use of synthetic detergents.

The Republic of Indonesia expects to export approximately 320,000 long tons of copra during 1952. If this forecast is realized, exports would be slightly above the 1950 level of 238,035 tons but would represent only 70 per cent of the postwar high of 455,483 tons during 1951. These totals do not include unrecorded shipments to Malaya which averaged about 90,000 tons per year during 1949-51.

The information obtained seems to indicate that slight decreases in the volumes of coconut oil consumed, accompanied by lower prices, are likely if there are no radical changes in the international situation. If a new process now being tested in the Philippines shows commercial promise, it is probable that there will be a downward trend in prices for some time to come.

**New Process for Extracting Coconut Oil**

A new patented process for obtaining coconut oil directly from the fresh coconut has been adopted and used in the Philippines since early this year by a plant in Laguna Province. Although the Laguna plant is capable of extracting about 5.5 short tons of coconut oil from some 40,000 fresh coconuts, the commercial possibilities of the new process are not yet known. Should the present operation prove successful, similar plants will be constructed in other places. With the new process, which eliminates the necessity of first producing copra, a high-grade coconut oil is reportedly obtained. Since the free fatty acid content is less than 0.10 per cent, the oil needs no refining. However, deodorization with steam, if only to destroy the organisms causing fermentation, is necessary if the oil is to be stored. (OP&DR, 5-5-52, p. 78)

**Cottonseed Oil--Figure 1 (J), Figure 2 (B)**

United States cottonseed production from the 1951 crop was reported at 6,325,000 tons, compared with 4,105,000 tons from the 1950 crop. The 1951 United States exports of cottonseed and cottonseed oil decreased sharply to considerably less than one-half the unusually large volume shipped in 1950. In terms of oil, the 1951 sales amounted to approximately 32,670 tons (31,564 as oil and 7,153 as seed) in contrast to 73,160 tons (71,787 as oil and 10,813 as seed) the previous year. Curtailed exports in 1951 resulted from United States production of almost 2,500,000 tons less seed in 1950 than in 1949. Over 65 per cent of the total seed and oil was sent to other North American countries, with Canada as the
principal market and Mexico ranking second in importance for the oil and Mexico the largest purchaser of seed. Sizable quantities of oil were sold to the Republic of the Philippines and to Colombia.

At the beginning of 1952 improved export demand created a firm tone temporarily, but heavy liquidation of futures soon caused prices to decline. In the latter part of February the decreasing prices of soybeans and soybean oil caused a further decline. The downward trend continued until late April when a reaction set in, and prices began to rise, supported by increasing consuming demand and scarcities of crude cottonseed oil. The Office of Price Stabilization at this time suspended control of cottonseed and other oils. The scarcity of crude oil continued, and the announcement of higher support prices by the USDA helped the upward price trend. In late June decreased buying interest caused prices to ease off somewhat.

Good production is expected in Brazil this year in spite of the delayed planting time caused by poor weather. In Turkey the acreage planted was about equal to last year's, and the crop is expected to be about the same. United States cottonseed oil production in 1952 is expected to be 50 per cent higher than last year. These factors indicate that supplies of cottonseed oil will be ample for this year; some authorities believe there will be a definite oversupply. The total cottonseed meal in sight is about 217,000 tons greater than last year, although in the second week in March about 588,000 tons more meal had been shipped than for the same period last year.

Olive Oil—Figure 1 (E), Figure 2 (H)

During January the price of olive oil remained firm, reflecting the high cost of shipments from Spain. A program was announced by the USDA to enable California and Arizona producers of oil olives to market their crop in the face of the abnormally low prices which resulted from a record crop of olives in the Mediterranean basin and a near-record crop in California in 1951-52. The United States produces approximately ten per cent of its total requirements of olives and olive oil, with the balance being imported from Mediterranean countries. The program will consist of offering CCC loans and purchase agreements for producers' olive oil meeting the requirements of the CCC. Prices generally followed the same trend as those of other edible oils. Declines in the price of edible oil during March, April, and May were the result of too much oil combined with a lack of demand. More buying interest was the main cause of price increases in June.

In 1951 the United States imports of edible olive oil dropped to approximately one-half of the twenty-year high of 1950—from 39,644 to 20,208 short tons. The decline occurred primarily because large stocks remained from the heavy buying of 1950. Inedible olive oil arrivals also decreased from 4,382 tons in 1950 to 1,939 tons in 1951, with over 90 per cent of the imports coming from Portugal. Spain and Italy supplied 95 per cent of the edible olive oil imports, with Spain alone accounting for 68 per cent. The relatively large shipments from Spain, in view of the
small 1950 production there, were made possible by record shipments of United States soybean oil to that country. The 1951 olive oil output of the Mediterranean was up 870,000 tons over 1950.

During 1951 Italy exported some 5,000 tons of oilseeds and 2,800 tons of vegetable oil, mainly soybean oil. Imports of vegetable oils amounted to 87,333 tons during 1951. Soybean oil from the United States (30,103 tons) was the largest single item.

This year the Spanish olive oil crop has been good (770,000 short tons anticipated), and Spain will probably become a net exporter of olive oil.

The Italian olive oil output is now estimated at 354,000 metric tons; with a substantial carryover from last year's large imports of vegetable oils and oilseeds, Italy now has an abundance of edible oils and a serious problem in the management of its stocks and prices. Imports will presumably be reduced in 1952, particularly imports of edible vegetable oils and oilseeds which compete with olive oil. Re-exports of certain fats and oils may also increase to relieve the pressure of large stocks on domestic prices.

These conditions seem to indicate that supplies of olive oil will be good this year, and that prices may be correspondingly lower.

Palm Oil--Figure 1 (M), Figure 2 (M)

The price of palm oil gradually declined from January through the second week in April as the result of gradually declining costs of replacements. In April prices of this and other oils reversed the decline, and with improving consuming demand prices began to rise. The increase in prices has continued.

World palm oil production in 1951 amounted to 3,980,000 tons. Palm oil and palm kernel oil exports in 1951 from the principal palm-producing areas of the world declined somewhat from the levels of the previous years. Shipments of palm oil in 1951 were estimated at 522,000 tons, a decrease of five per cent from 1950. The African continent supplied 70 per cent of the total; Indonesia, 20 per cent; and Malaya, 10 per cent. The decline in exports from the previous year is essentially explained by the drop in exports from Nigeria, the largest exporter since prewar and the source of about one-third of the 1951 total. Less significant decreases occurred in Malaya, French Cameroons, French Togo, and Portuguese Africa.

The following new development in stripping oil mediums may affect the use of palm oil, although probably not at any time in the very near future.

Palm Oil Substitute

A new stripping oil medium developed by Archer-Daniels-Midland Company is said to offer important economies and improved results in the
hot dip tin and tin-plating industries. The new composition overcomes the most serious objections to palm oil and other traditional stripping oils. Under the high temperatures at which oil stripping is usually done, palm oil gradually decomposes and increases in body viscosity. It generally becomes necessary to replace at least 25 per cent of the oil every two weeks to maintain satisfactory performance.

In contrast, the new material is said to be so stable that decomposition is negligible. After a six-months' test it still retained all the original properties required of a satisfactory stripping oil. No additions were necessary except to replace the oil carried away as film on the finished product. (OP&DR, 1-14-52, p. 49)

Palm Oil in Honduras

In 1942 the United Fruit Company began an investigation of the possibility of producing palm oil in Honduras as part of the search for new crops to combat the world shortage of edible oils. Selected varieties of the African oil palm (Elaeis guineensis) from the East Indies, the Malay States, and West Africa were planted in subsequent years, and the Java variety was found to be the highest yielding. (EB, 3-52, p. 22)

Peanut Oil--Figure 1 (N), Figure 2 (J)

Price developments concerning peanut oil were mostly reflections of other widespread developments in the entire field. At the beginning of the year government releases of peanuts for crushing caused prices to gradually decline, while prices of peanut meal were higher. The financial panic in India during March may have had some effect on the continuing decrease in prices.

The price support for the 1952 crop of peanuts was announced as an increase of nine dollars per ton over the 1951 average support prices. This may be increased proportionally if the parity price at the beginning of the marketing season is higher than that upon which the announced price is based.

The price of oil rallied slightly during April, then declined with other oils as a result of the liquidation of futures and lessening of demand. During the first week in May reports that the Government would reduce releases of peanuts for crushing purposes during the remainder of the season resulted in suddenly increased demand and caused a sharp increase in oil prices. The increasing prices continued for some time, caused both by the Government action and by increasing demand.

World peanut production in 1951 approximated the estimated record high of 1950. Output is now placed at 11,209,000 short tons, which is only one per cent below the 1950 production. Significant decreases from 1950 in the harvests in India and the United States were not entirely offset by the sizable increases in French West Africa and Nigeria, and to a lesser extent in other African countries, Indonesia, Burma, Argentina, and Brazil.
United States exports of peanuts and peanut oil in 1951 amounted to approximately 149,320 short tons in terms of unshelled nuts. This is an increase of over one-third from the 1950 volume but 60 per cent less than the record high tonnage exported in 1949. Total shipments in 1951 represented 15 per cent of 1950 production, whereas the all-time high of 1949 represented one-third of the record production of 1948.

At the beginning of the year the demand for peanut meal was greater than the supply, and shortages threatened. This was due principally to the acute shortage of other feed meals. The demand has continued, and it has been predicted that a serious shortage of peanut meal will occur. Supplies of peanuts on May 31, 1952, excluding shelled oil stock, totalled nearly 560 million pounds, farmers' stock equivalent. At this time the supply of peanuts was about eight per cent above the 518 million pounds for the same date last year.

It was predicted that about 2,158,000 acres of peanuts would be planted this year, which is a decrease from the 1951 acreage of 2,593,000 acres.

Brazilian plantings of peanuts were delayed because of poor weather, and crops from southern Brazil are not expected to be exceptional. The Uruguayan production of peanuts has been forecast at only 4,850 tons, against 9,520 tons during the previous season. Dry weather is the principal cause of the decline in production estimates.

In Turkey, peanuts, though only a minor crop, are expected to be grown in increasing quantities in the future as an export crop, although the total acreage is not expected to ever become very large.

India's export quota for established shippers of peanuts and peanut oil in the first quarter of 1952 was 21,000 long tons in terms of oil. Shipments are allowed to go to all approved destinations, except that one-seventh of the quota, where shipments were greater than 50 tons, must go to Burma.

Not much change is expected in the peanut market, except those fluctuations which are the result of seasonal operation. It is the authors' opinion, however, that the current drought in the South may cause the crop to be somewhat smaller this year.

New Uses for Peanut Oil and Peanuts

Peanut oil is being mixed with high-grade Diesel oil for use as an experimental fuel in Diesel engine tractors in India. The experiment resulted from the threatened petroleum shortage caused by trouble in Iran. A highly refined peanut oil was used in an International Harvester Unit. There was no starting trouble, and the engine ran smoothly. However, toward the end of the 50-hour experiment smokeiness developed in the exhaust, and oil consumption increased. Further experiments are planned, but there is not very much chance of the expedient being widely used unless the price of peanut oil goes down. (CD, 2-52, p. 16)
Several synthetic fibers have been made from peanuts in recent years. Ardiil, which is similar in appearance to wool, has been made from extracted peanut meal. The Southern Regional Laboratories have produced the fiber Sarelon from peanuts. (CD, 1-52, p. 17)

Pine Oil

For the first few months of 1952 there was a serious shortage of pine oil in Canada as a result of unusually large consumption by the mining industry.

Rapeseed and Mustardseed Oils—Figure 1 (K), 1 (O), Figure 2 (G)

Rapeseed and mustardseed oils followed the same general trends as other edible oils. Prices gradually declined over the period as a result of too much oil, lack of demand, heavy importations, the financial panic in India, and rumors of peace in Korea.

Shortly after the beginning of the year, India’s Ministry of Finance announced reductions in Indian customs duties on exported mustardseed oil.

India’s 1951-52 rapeseed and mustardseed oil crops are expected to be smaller than last season’s. Production of the two is not expected to exceed 896,000 tons.

IV. NEW OILS

Black Spruce Oil

An estimated five million pounds of black spruce oil are available annually from Ontario, calculated from the amount of foliage cut. The perfume industry can use only a small amount of this, and new uses must be found. Black spruce oil is one of the richest natural sources of bornyl acetate and may also be used for synthetic camphor. (EB, 3-52, p. 17)

Gokhru Oil

Gokhru, from India, has been mentioned as a promising source of an oil said to have excellent drying properties. The yield is estimated at about 500 to 600 pounds (30 to 33 per cent semidrying oils) per acre. The cake is high in phosphorus and nitrogen. (C&EN, 4-7-52, p. 1432)

Grapeseed Oil

The oil pressed from the seed of wine grapes has been used in the paint industry in Italy for twenty years and could probably be made available in this country. It could play an important role in the protective coatings industry when other fatty oils are scarce. The oil has a slightly higher viscosity than linseed oil and, when pigmented with zinc oxide, yields paints of better moisture impedance than corresponding linseed oil paints. (PO&GR, 1-17-52, p. 35)
Kamala Oil

Indian scientists are investigating kamala oil, which is said to be a substitute for tung oil. The oil, extracted from the seeds of the Kamala tree, dries to a natural wrinkle finish without the application of heat. It is generally better than tung oil, and the seed has an oil content of about 40 per cent. The seed has long been familiar as the source of an orange dye. Previous development as an oil crop has been hampered by the oil extraction process involving expensive organic solvents.

(P0%CR, 1-3-52, p. 13; PM, 4-52, p. 119)

Mowrah Oil

Mowrah oil has drawbacks for edible purposes—high acidity, deep color, unpleasant odor, high unsaponifiable content. Alcoholic refining, however, results in an improved product, and hydrogenation of the refined oil gives products similar to mutton tallow and cocoa butter.

(C&EN, 4-7-52, p. 1432)

Nim Oil

This oil compares favorably with other vegetable oils and, when hydrogenated, can be used for making high-grade soaps or high-melting stearins (C&EN, 4-7-52, p. 1432). It also contains a readily extractable bitter principle of pharmaceutical interest.

(0P%DR, 4-7-52, p. 38)

Pilchard Oil

An Italian firm has introduced specially treated pilchard oil as a possible substitute for linseed and tung oils. The crude oil is boiled under vacuum, refined, and treated with propane. It is said to be highly resistant to sea water and loses its original fishy smell. The color is clear, acidity is low, and it can be used with basic or reactive pigments without fear of clotting or thickening.

(PM, 12-52, p. 452-54)

Pisa Fat, Khakan and Phulwar Oils

Studies of Indian pisa fat, taken from the seeds of the pisa tree, as a possible substitute for coconut oil indicate that the mixed fatty acid of the kernel fat is 96 per cent lauric acid and four per cent oleic acids. The seed has a kernel rich in fat and an outer covering which is removed before crushing. Average samples of the seed yield 48 per cent fat by solvent extraction, or 32 per cent fat by hot expression. The seed contains 31 per cent foreign matter and shells, six per cent moisture. (S%SC, 1-52, p. 79) Recent research in India has also indicated that khakan and phulwar oils can replace coconut oil in soapmaking.

(S&SC, 4-52, p. 95)

Queenroot Oil

Stillingia sylvatica, commonly known as queen's-delight or queen-root, is native from Florida to Texas and from Missouri to Virginia.
A root extract of it has had medicinal use for many years, and recent investigation has shown that the seed oil may be suitable as a drying oil for paints and varnishes. (EB, 3-52, p. 22)

**Rice Bran Oil**

A recent development in the industry is the recovery of oil from rice bran. Texas, Arkansas, and Louisiana produce three-fourths of the rice grown in the United States. About ten per cent of rough rice is milled out as bran, containing 15-17 per cent oil. In the fall of 1949 a continuous solvent extraction plant, having a capacity of 80 tons of rice bran per day, began operating in Houston. Two other plants have been placed in operation since then. These three plants have a combined capacity equivalent to more than half of the total rice bran produced in the Southwest. Other plants are being planned for Arkansas and Louisiana. (CD, 3-52, pp. 4-6)

**Safflower Oil**

This oil is already well into the commercial market, but interest in its production in the United States is of fairly recent date. The major foreign producing countries are Egypt, India, and the Orient. Basically, safflower is a drying oil crop, but the meal remaining after the oil has been extracted is used as a livestock feed because of its high protein content. Safflower oil has aroused considerable interest both from the farmers who have found it profitable to grow the seed and from alkyd resin producers and manufacturers who have found good qualities in the oil. It is estimated that the 1952 harvest will produce about twice as much oil as that from the 1951 crop. (Additional information concerning safflower may be obtained from the following source: Woodward, R.E. and Severson, G.M., Industrial Survey of Safflower. Agricultural Experiment Station, University of Nebraska, Bulletin No. S-3, Lincoln, 1951, 35 pp.)

**Safflower and Tobacco-Seed Treatment**

Stand oils prepared from raw tobacco and safflowerseed oils were similar when compared to the corresponding linseed oil products. Isomerization was tried in the presence of anthraquinone, nickel-carbon catalyst, and activated silica; modified oils having good drying properties were obtained with the first two catalysts mentioned. Varnishes of medium oil range with the ester gum made from the treated oil were similar to the corresponding linseed oil varnishes. Their white paints containing titanium dioxide gave films similar to those of linseed oil paints, but the color retention was better. (JAOCS, 1152, p. 38)

**Safflower Oil Polymerization**

The polymerization rate of safflower oil is sufficiently rapid to warrant its use on a commercial scale; with the proper choice of polymerization temperature, safflower can be bodied at the same rate as linseed. The increasing rate at which safflower bodies in the high viscosity
ranges invites further investigation. Safflower oil bleaches considera-
bly better than linseed oil and is equal to or better than soya in this
respect. (PM, 6-52, p. 225)

Sesame Oil

For the past five years an intensive research program has been under
way to develop new strains and varieties of sesame. This oilseed yields
more oil to the acre than any other annual oilseed. In the past it has
not been amenable to mechanical harvesting because of its tendencies to
ripen unevenly and to drop its seed at maturity. This oil has many
possible uses and is now being used for making shortenings, cooking oils,
and margarine, and in soaps, drugs, paints, and insecticides. The pressed
cake or meal makes an excellent livestock feed because of its high pro-
tein content. The oil and seed keep for several years without becoming
rancid. New, nonshattering varieties of the plant have recently been
developed, and trial field plantings have been made during the past year.
The present oil mills of the South could, with only minor modifications,
be equipped to extract oil from the sesame seed. (The Cotton Gin and
Oil Mill Press, 1-20-51; CD, 3-52, pp. 4-6)

Sorghum Grain Oil

Sorghum grain was found to contain two-thirds as much oil as corn
and 50 times more wax. The wax was similar to carnauba and could be
extracted from the unground grain by hot solvent. The grain oil was
found to be similar to corn oil and could be used as substitutes for
salad oils or hydrogenated and made into oleomargarine. (American
Miller and Processor, 1-47)

Sunflower-seed Oil

This oil has been in fairly wide production in other parts of the
world for some time. It is sometimes used as an extender for some of
the major drying oils, but it is usually considered an edible oil.
Recently it has attracted attention in the United States, some research
has been conducted to determine its properties. After three years' ex-
posure to laboratory temperatures there was no development of rancidity,
chemical changes, or off-flavor. The oil, when stored under refrigera-
tion, showed no precipitation or separation. The meal contained 52.5
per cent protein. (JAOCs, 2-52, p. 74)
V. NEW TECHNOLOGICAL DEVELOPMENTS

Solvent-Extraction Process for Cottonseed, Soybean, and Rice Bran

A new process for solvent-extracting oil from cottonseed and other oilseeds has been developed on a pilot plant scale at the Federal Government's Southern Regional Research Laboratory. The process, which is especially adapted to use by small mills, is called "filtration-extraction" because it involves the use of a continuous vacuum filter as a major operating unit. The process has worked successfully with cottonseed and, with certain modifications, also proved to be suitable for the oil processing of rice bran and soybeans. Experiments with other oilseeds are under way.

In changing to the filtration-extraction process, the investment required for equipment and the cost of operation are both relatively low; yet high-quality oil and meal are produced. No radical or expensive departure from the operations now used to prepare cottonseed for hydraulic or screw dressing is required, although the method of preparation is modified. The amount of solvent required is small, and conventional equipment can be used to remove it from the oil and meal after extraction. The equipment for the oil-extraction step requires relatively little floor space. The pilot-plant filter in use at the laboratory has a capacity of 24 tons of cottonseed a day but is only slightly larger than a family washing machine. (CD, 3-52, p. 16)

Fat-Producing Micro-Organisms

Some vegetable fats can be produced by micro-organisms such as the strains found in Penicillia, Aspergilli, Endomyces, and others. Submerged culture methods allow batch pilot-plant-scale production. No microbial process has been evolved to date that can compete economically with edible fats derived from plants or animals. The cost of microbial processes runs three to ten times higher than the conventional methods, but the process may be important in times of emergency. (JAOCs, 1-52, p. 35)
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VI. APPENDIX
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BIBLIOGRAPHY

The complete list of journals scanned in this survey follows. The abbreviations used in this report appear after the name of each periodical.

Business Week (BW), Jan. 5--July 26, 1952.
Chemical and Engineering News (C&EN), Jan. 7--July 28, 1952.
Chemical Engineering (CE), Jan.--July, 1952.
Chemical Week (CW), Jan. 5--July 26, 1952.
Chemurgic Digest (CD), Jan.--July, 1952.
Economic Botany (EB), Jan.--June, 1952.
Foreign Commerce Weekly (FCW), Jan. 7--July 28, 1952.
Naval Stores Review (NSR), Jan. 5--July 26, 1952.
Paint Manufacture (PM), Jan.--July, 1952.
Paint, Oil and Chemical Review (POCR), Jan. 3--July 31, 1952.
Oil, Paint and Drug Reporter (OPDR), Jan. 7--July 28, 1952.
Soap and Sanitary Chemicals (S&SC), Jan.--July, 1952.
Tung World (TW), Jan.--June, 1952.

Also examined in this survey were:
The Agricultural Index (Jan.--June, 1952.)
The Industrial Arts Index (Jan.--July, 1952.)
The International Index to Periodicals (Jan.--June, 1952.)
The Reader's Guide to Periodical Literature (Jan.--July, 1952.)
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Figure 1. Weekly Price Trends of Fats and Oils.
Figure 1. (Con't.) Weekly Price Trends of Fats and Oils.
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Figure 1. (Con't.) Weekly Price Trends of Fats and Oils.
Figure 2. Monthly Factory Consumption of Fats and Oils (November, 1951-May, 1952). (continued)
Figure 2. Monthly Factory Consumption of Fats and Oils (November, 1951-May, 1952).
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TABLE I  
MONTHLY FACTORY CONSUMPTION OF FATS AND OILS
(November, 1951--May, 1952)
(Thousands of Pounds)

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<td>36,159</td>
<td>47,698</td>
<td>42,364</td>
<td>45,222</td>
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<td>161,714</td>
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<td>196,244</td>
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<td>8,590</td>
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<td>6,301</td>
<td>5,792</td>
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<td>Castor Oil, No.1 crude</td>
<td>4,593</td>
<td>4,527</td>
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<td>5,234</td>
<td>4,898</td>
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<td>2,204</td>
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<td>1,868</td>
<td>1,915</td>
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<td>Castor Oil, dehydrated</td>
<td>1,218</td>
<td>1,262</td>
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<td>1,475</td>
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<td>Tung Oil</td>
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<td>3,591</td>
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<td>2,907</td>
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<td>350</td>
<td>436</td>
<td>430</td>
<td>434</td>
<td>478</td>
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(1) Data obtained from Facts For Industry, United States Department of Commerce, Washington, D. C.
(2) Volume not listed separately.
Industrial Raw Materials of Plant Origin

II. Recent Developments in Vegetable Waxes, Gums, and Resins

T. A. WASTLER
P. M. DAUGHERTY
H. H. SINEATH

BULLETIN NO. 15

This work was done through contract with the Division of Plant Exploration and Introduction, Bureau of Plant Industry, Soils and Agriculture Engineering, United States Department of Agriculture, under the Research and Marketing Act of 1946.

ATLANTA, GEORGIA
1953
FOREWORD

This bulletin is the second in a series of publications dealing with industrial raw materials from plant sources; it discusses the economic and technological developments in the field of vegetable waxes, gums, and resins between January 1 and December 31, 1952.

Many of those actively interested in these materials do not have the opportunity to read and assimilate the pertinent but scattered literature covering the field. A survey of this current literature is compiled here and is presented so that, with a minimum of expenditure of time and effort, a person interested in recent occurrences in the field can obtain an overall view of the entire industry and of developments concerning any specific material of commercial importance (or of possible future importance). The information is as complete as possible, although excessive details are omitted. The opinions expressed here are those of the editors of the journals surveyed unless otherwise noted, and those sections discussing new developments include complete references for readers who desire additional information.

The authors and the sponsoring organization hope to determine whether or not a periodical summary of this type would prove valuable to those concerned with vegetable waxes, gums, and resins. Comments on the value and utility of continuing this bulletin will be appreciated.

This survey has been made possible by the Division of Plant Exploration and Introduction, Bureau of Plant Industry, Soils and Agricultural Engineering, United States Department of Agriculture under the Research and Marketing Act of 1946. It was conducted at the Engineering Experiment Station of the Georgia Institute of Technology, Atlanta, Georgia. The survey is part of a larger program, initiated by C. O. Erlanson, Head of the Division of Plant Exploration and Introduction, to investigate the needs of industry for plant-derived raw materials and to conduct market surveys for various commodities worthy of possible future development. The authors are grateful to those libraries, industrial organizations, and individuals who have cooperated in this program.

Atlanta, Georgia
January 23, 1953

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Research Assistant

P. M. Daugherty,
Research Assistant

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<td>31</td>
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Unless otherwise noted, the market statistics contained in this report were obtained from the market sections of the journals surveyed.
SCOPE OF THE SURVEY

This survey includes the information of economic or technological importance which was found in the literature published during the period covered. When the information has been available, graphs of price trends and volumes consumed have been presented for each wax, gum, or resin, together with comments about any significant developments affecting the economic position of any of these commodities. Any reported scarcities and the probable reasons for their existence are mentioned. New developments, possible new raw materials and new products are discussed, and any recent technological developments which may affect the position of any vegetable wax, gum, or resin are included. Opinions on the supply and price trends to be expected in the near future, as well as reported estimates of future production, are also presented.

To obtain the information given in this bulletin, a careful, continuous page-by-page scanning of trade literature was conducted; the pertinent articles were abstracted. Nineteen selected journals were surveyed; these are listed in the Appendix. Reports of the United States Department of Commerce have been freely used, and some reports and bulletins published by various experiment stations were consulted. Several standard periodical indexes were examined under pertinent headings; these are also listed in the Appendix.
I. GENERAL SUMMARY OF DEVELOPMENTS

As consumers came to believe that the Korean War was not going to cause a world-wide war, the trend of commodity prices started down in 1952. At the same time farmers had been encouraged to produce more by the high prices prevailing in 1951; the pressure of this added production increased the downward trend, and many prices sank to the government support level, not only in the United States but also in other countries, such as Brazil and Argentina. Many of the commodities discussed in this bulletin were so affected.

Waxes have generally been in good supply this year in spite of a severe drought in the carnauba-producing areas of Brazil last year. The prices of carnauba wax were so high for the major part of 1952 that sales decreased, with consumers turning to cheaper waxes for their requirements. New methods of determining the presence of additives in waxes have been developed, and many carnauba substitutes have been investigated. Perhaps the most significant development in the vegetable wax industry during 1952 was the decree by the Mexican government prohibiting the exploitation of candelilla wax during the greater part of 1953.

The natural gums and resins markets were generally quiet during 1952; practically the only disturbing factor was the devaluation of Indonesian currency in the Spring, which caused some price decreases. Some new sources of agar were reported, as were some new applications of vegetable gums and resins.

Production of naval stores was lower in 1952, and prices also decreased. It was hoped that some new uses which were found for naval stores would open up new markets for the raw materials. The production of maleo-pimaric acid and terpene hydroperoxide catalysts, and new uses for tall oil in the protective coatings industry are examples.

II. WAXES

Market Developments--Figure 1, Figure 4, Table I

Vegetable waxes, while representing only about three per cent of the total volume of waxes consumed, account for about 25 per cent of the total value of waxes consumed. In spite of the relatively small percentage of vegetable waxes used, the actual volume used is considerable, amounting to about 31.5 million pounds in 1950 and 26.3 million pounds in 1951. The costs of vegetable waxes are so high compared to those of other waxes that only certain properties which have not yet been duplicated in lower-priced waxes keep the demand for them active.

A few fields consume considerable quantities of wax, but, in general, wax products go into a broad variety of applications in a great many industries. Purchases are frequently made in fairly small quantities. Vegetable waxes are consumed in large quantities in polishes and carbon paper,
with a fair-sized amount of candelilla wax being used in chewing gum. The polish industry uses more types of wax than any other. Of the 34 million pounds consumed annually in this industry, about one-half is paraffin and one-quarter is carnauba. In carbon paper manufacture rough estimates indicate that, of about 6.5 million pounds of waxes consumed annually, four million pounds are carnauba, one million pounds are ouricuri, and the balance is divided among candelilla, sugar cane, and montan waxes.

Carnauba wax, imported from Brazil, and candelilla wax, imported from Mexico, are both subject to price regulations established by the governments of those countries and, therefore, do not show the normal price variations of free market commodities. In addition the United States Government has established a ceiling price on candelilla and carnauba waxes, which is currently governed by "Ceiling Price Regulation 31--Imports," Office of Price Stabilization, Washington, D. C.

Carnauba Wax

The 1951-52 Brazilian carnauba crop from the northeastern part of the country was affected by a severe drought which caused large-scale migrations of the labor force from the stricken area. The unfavorable climatic conditions also retarded full development of the fronds from which the wax is taken; this condition was especially noticeable in the second cutting. The industry has also been influenced by the growing trend toward the use of machines to extract the wax powder from the fronds. This method increases wax output, as considerable amounts are wasted when the hand method is used.

A relatively favorable price was offered for carnauba in the early part of the crop year, but prices were later reduced somewhat. In May and June prices were raised and the Brazilian Trade Bureau refused to lower them. Many trade sources thought that the Brazilian government's price-supporting tactics would ruin the market for carnauba. Later in the year prices were reduced slightly. The wax was reported in very good supply, and even some surplus was reported because of the high price.

The National Production Authority Advisory Committee reports that full compliance with the export regulations set up by the Brazilian government may cause an artificial shortage of carnauba wax. One regulation requires Brazilian consular or trade bureau representatives to examine and certify imports. This regulation puts American importers in the position of having to aid the Brazilian government in enforcing its export regulations.

Candelilla Wax

The price of candelilla wax has remained at a steady level during 1952. This probably results from the very high price of carnauba and the controls imposed by both the Mexican and United States Governments.
It was expected that candelilla wax production in Mexico would be appreciably reduced the latter part of this year by the severe drought conditions there, and that this condition would continue until after the rain in December and January.

A Mexican presidential decree, published in the Diario Oficial under the date of December 6, 1952, and effective the day after publication, totally prohibits the exploitation of candelilla from December 1, 1952 until September 30, 1953. The production of candelilla has shown a decreasing trend in recent years, and this step has been taken to halt extensive exploitation of candelilla plantings in the states of Chihuahua, Coahuila, Zacatecas, Nuevo Leon, Durango, and San Luis Potosi, where the species has been endangered to the point of extinction.

The present concessionaires or holders of exploitation permits have been requested to turn in their permits to local agricultural authorities, and those having stocks of candelilla wax on hand are asked to submit a written report on quantities and locations of those stocks within a period of 15 days from December 1, 1952. No movement of candelilla wax will be permitted from deposits or warehouses without express authorization of the Mexican Department of Agriculture.

It is generally believed that candelilla wax will be difficult to obtain from Mexico next year.

Other Waxes

In general, the other vegetable waxes have been fairly stable during 1952. Both domestic and imported grades of sugar cane wax had price declines during the year, but these declines were preceded and followed by constant price levels. Ouricuri wax varied in price with variations in carnauba; this is to be expected since ouricuri is widely used as a low-priced substitute for carnauba.

New Technical Developments

Qualitative Test to Detect Hydrocarbon Adulteration of Carnauba

A short, qualitative test for determining any substantial hydrocarbon adulteration of carnauba wax has recently been developed. Older tests have been considerably more involved and have taken more time to conduct. The new method of testing consists of dissolving a given amount of wax with a standard volume of isopropanol in a beaker, then decanting the liquid, dissolving the residue in a further volume of solvent, and decanting a second time. After the second decanting the beaker is allowed to cool. The presence of oily rings around the side of the beaker after cooling indicates the presence of paraffin or microcrystalline waxes. A heavy sediment in the bottom of the beaker indicates the presence of ester gum or a hydrocarbon resin. (S&SC, 9-51, p. 139)
Instrumental Methods for Detecting Additives to Waxes

Several methods of instrumental analysis have been tested for possible use in analyzing wax compositions. The use of refractive index comparisons has proved extremely valuable in determining the amount of additive present in a known wax base. Infrared spectroscopy is a very accurate method for determining the presence of additives and, in many cases, for determining what the additive is. Both of these methods have the great advantages that only a drop of material is required for analysis and that the analysis is fairly rapid. (S&SC, 11-52, pp. 127, 129, 131; S&SC, 12-52, pp. 181, 183, 185)

Replacements for Vegetable Waxes

During recent years the advancing prices of carnauba, the most widely used vegetable wax, have compelled its users to look for less expensive replacements and to investigate possible new wax sources. Five classes of waxes are available for consideration: animal waxes, synthetic waxes, petroleum waxes, vegetable waxes, and composition waxes. Representatives of all of these classifications have been tried, but carnauba is still preferred by most users.

A satisfactory substitute for carnauba wax must have several important characteristics. Not only must it possess high gloss and hardness and have a high melting point (Federal specifications call for a softening point for the solids of not less than 80° C.), but it must also have good emulsifying characteristics. The emulsified wax must not be a cloudy liquid, but a transparent one, especially when laid down in thin layers. In addition, it would have to exhibit characteristics of toughness, water repellency, absence of tack, and light color. While the development of synthetic waxes has progressed in recent years, it has only made small inroads on the demand for carnauba.

Several vegetable waxes have been widely used as substitutes for carnauba wax, although none has proved entirely satisfactory. Many others have been mentioned as possible substitutes, but most of these have never been commercially developed to any great extent. The market is open for good, moderately priced vegetable waxes.

Candelilla Wax

This wax occurs as a coating on the stems of a weed native to Mexico, where most of the material of commerce originates, and to some parts of Texas. It has been used successfully as an extender for carnauba stocks. The wax itself is not entirely suitable as a replacement for carnauba since the melting point is somewhat low and the commercial wax usually contains a considerable quantity of resinous components which impart an objectionable tackiness. Recently the high prices asked for candelilla wax have hindered its use to supplement carnauba wax. In addition, candelilla is employed for various uses in which carnauba is not suitable.
Recently an industrial survey on candelilla was undertaken at the Georgia Institute of Technology in an attempt to establish its future market potential. This work was an outgrowth of a preliminary survey carried out in 1951 on the needs of industry for raw materials derived from plant sources. The results of this industrial survey indicated that the domestic production of candelilla would be worth considering, although additional experimental work on the techniques and economics of cultivation, harvesting, and processing would be desirable before any major program of domestic production was undertaken. A bulletin revealing the findings of the survey will be published in the near future.

Cauassu Wax

The leaves of the cauassu (Calathea lutea), a tall herb of the Amazon region, are potentially an important source of a commercial wax. The crop growth of this plant in semitropical areas of the United States is believed to be quite possible. Reports from Brazil indicate that the plant is easily grown and that the wax yield is very good. About 30,000 seedlings can be planted on one acre of land and can be harvested a year after planting. In subsequent years two harvests may be collected annually; this would mean an annual crude wax yield of about 800 pounds per acre. The wax is removed from the dried leaves by mechanical beating or by extraction with hot water.

Preliminary tests indicate that the wax is similar to carnauba and can be used for many of the same purposes. It has the disadvantage of containing a resin which would require removal by solvent refining for some applications. (CD, 6-52, p. 5; Hill, A. F., Economic Botany, McGraw Hill Book Company, Inc., New York, 1952, p. 207)

Douglas Fir Bark Wax

The bark waste from Douglas fir logging operations contains several extractives of commercial interest. Among these is a wax having a melting point in the range of 59° to 63° C. This wax is reported to be harder than beeswax, but not as hard as carnauba; however, by chemical treatment the Douglas fir wax can be made superior to carnauba in this and other respects.

Since the bark also contains other marketable products such as tannin and dihydroquercetin, the possibilities for the economic production of the wax are increased. The bark contains 28 to 43 per cent total extractives. (CD, 6-52, p. 5; CW, 9-27-52, p. 45)

Jojoba Wax

The seeds of a shrub which grows wild in large areas of the southwestern United States and northern Mexico contain about 50 per cent liquid wax. This liquid wax has properties which have suggested its use as a direct replacement for sperm whale oil. Possibly more important is the fact that the liquid wax can be transformed into a hard white wax by
hydrogenation. Claims are that this hydrogenated wax could serve well as a replacement for carnauba or other hard waxes of commerce. Experimental furniture and automobile polish compositions of jojoba wax proved to be equal to or superior to some of the popular polishes now on the market. Insufficient experimentation has been conducted to establish fully the potentialities of this wax from jojoba seeds. Since the wax is extremely pure, it might be advantageous to utilize other waxes as extenders in its compositions.

A bulletin reporting the results of a recent industrial survey on the potentialities of products of the jojoba plant will be published by the Georgia Institute of Technology in the near future.

**Ouricuri Wax**

Ouricuri is somewhat similar to carnauba in color and hardness but is cheaper in price. It has been used as a carnauba substitute in floor waxes, shoe creams, and other polishes, although its higher resin content makes it somewhat inferior.

Ouricuri is derived from the undersurface of a tropical American palm (*Scheelea martiana*) and is removed by crude methods--scraping from the leaf with a knife, melting, and straining. (CW, 9-27-52, p. 45)

**Sorghum Grain Wax**

Sorghum grain contains about 0.3 per cent wax with a reported melting point of 80° to 84° C. The wax is concentrated in the hull or bran and is removed by solvent extraction, and the wax so removed is white. Comparison of the chemical characteristics of carnauba and sorghum grain waxes indicates that sorghum grain wax has higher acetyl, acid, and iodine numbers and a lower saponification number than carnauba wax. Sorghum grain wax also contains a lower percentage of esters and nonsaponifiable material than carnauba wax, and a hydrocarbon fraction which is absent in the latter. (JAOCS, 3-51, pp. 121-3; American Miller and Processor, 1-47).

**Sugar Cane Wax**

Sugar cane wax is now being produced commercially from the clarifier muds resulting from sugar refining. Two methods of extraction have been proposed. One uses selective solvent extraction, and the other employs vacuum distillation and a chromic acid bleach. The crude wax as removed by solvent extraction is dark and soft, but it can be hardened and lightened by further refining and bleaching.

As a byproduct of cane sugar, the wax is available at the present from sources in Australia, Cuba, California, and Louisiana, the imported wax being cheaper than the domestically produced wax. The yearly potential production of hard wax from the Cuban sugar mills alone would be about 60 million pounds, more than the world's combined production of
carnauba, ouricuri, and candelilla. Potential uses for the wax are in water-emulsion polishes, carbon paper, and paste polishes, as pigment dispersers, and for coatings. (CW, 9-27-52, p. L7; S&SC, 3-51, p. 110)

III. GUMS AND RESINS

Market Developments—Figure 2, Figure 5, Table II

The vegetable gums and resins market has been fairly slow during 1952. Prices of Far Eastern gums and resins have declined during the year, partly because of the lower world price level of commodities in general, partly as a result of the devaluation of Indonesian currency, and partly because of declining prices for synthetic resins, which declined with the falling price of glycerine.

It is believed that, if the prices of natural resins would go low enough, American consumers might use more natural resins unless, of course, the cost of synthetic resins also went down a corresponding amount. Since World War II, however, the prices of natural resins have been controlled to a great extent by European buyers and not by American buyers because European buyers, who do not have the United States dollars to buy synthetic resins here, have obtained large amounts of natural resins on the world market, thus pushing prices up.

Agar

Agar has been short in 1952 as a result of increased demand by the food industry and because stocks in this country are limited. Reports are that supplies in Japan are also limited.

Gum Arabic and Gum Tragacanth

Trade in gum arabic and tragacanth has been seriously hampered by hostilities and by the generally unsettled conditions in the Middle East. No easing of conditions is anticipated at this time.

Sandalac Gum

The government of French Morocco now controls both the collection and the export of sandarac gum in an effort to conserve the trees, which have decreased sharply in number because of the unrestrained collection of gum. At the present only parts of the areas where the trees grow are worked for the gum each year. As a conservation measure, the Moroccan policy is excellent; this policy has, however, also been responsible for the excessively high prices that must be paid when sandarac gum is available.
New Technical Developments

Hydrogenating Natural Resins

The oil obtained by moderate pyrolysis of rosin, copal, kauri, or damar gum can be hydrogenated at high temperature and pressure in the presence of a heavy metal catalyst to give a stable oil that may be used as a lubricant or transformer oil. (French Patent 973,251; Chemical Abstracts, 1952, col. 9324)

Organic Colloids in Drilling Muds

Recent research has been conducted to investigate the usefulness of natural gums and similar colloids of Iranian origin in reducing the water loss of both salt-water and fresh-water drilling muds. Numerous gums were tested and several were found to be quite effective in reducing water loss. The best at temperatures of about 68° F. were found to be gum ghatti, gum tragacanth, gum shiras, quince-seed gum, and locust bean gum. At higher temperatures (180° F.) the effectiveness of gum shiras and locust bean gum was even greater. It is believed that such gums could be widely used in the United States and the Near East to increase the efficiency of drilling muds. (The Petroleum Engineer, 4-52, pp. B45-B52).

Methods of Differentiating Between Certain Jalap Resins

Brazilian jalap resin is slightly soluble in ethyl ether and fairly soluble in water. The aqueous solution of Brazilian jalap forms a persistent froth when shaken and is yellowish brown in screened ultraviolet light. The purified resin has a specific rotation of about -20° and a melting range of 94-100° C. Brazilian jalap resin can be distinguished from Vera Cruz jalap by comparing the appearance of the resins, their chromatograms in screened ultraviolet light, their solubility in water, their specific rotation, and their melting point range. It can be distinguished from Orizaba jalap resin by comparing the previously mentioned properties and their solubility in ethyl ether. (J. Pharm. Pharmacol., 1951, pp. 286-94; Ibid, 1952, pp. 304-10)

New Gum and Resin Sources

Agar and Other Seaweed Derivatives

Three types of Philippine seaweed (Hypnea musciforms, Gracilaria lichenoide, G. canaleculta) have shown promise as sources of agar. The agar thus far prepared does not meet the specifications of the United States Pharmacopeia, but it is believed that the quality could be improved by better methods of processing. (FCW, 2-25-52, p. 18)

Laminarin, a derivative of seaweed, can be used as a component of talcum powder, as a substitute for blood plasma, and as a surgical powder readily absorbed by tissue. (AP&EDR, 2-52, p. 135)
Resin from Cashew Nut Shells

The cashew nut shell yields a liquid resin which, when combined with ethyl cellulose, forms a binder for pigments. This binder is especially useful for fabrics. (SNL, 8-16-52, p. 105)

Mucilaginous Materials from Flaxseed

A mucilage suitable for use in medicinal preparations, in water paints, and for the manufacture of soluble fibers can be obtained from solvent-extracted flaxseed meal. The meal is air-separated and screened to obtain kernel and hull fractions, the kernel being high in protein and the hull high in mucilaginous materials. The mucilage can be removed by treating the hull fraction with acid and centrifuging, and it can then be concentrated by evaporation under reduced pressure and spray drying. The dried product is substantially proteinfree and fiberfree and forms an acceptable gel in a 4.4 per cent aqueous solution. (U. S. Patent 2,593,528; Chemical Abstracts, 1952, col. 9333)

Arabogalactan, Gum Arabic Substitute

Waste from the milling of Western Larch trees can be used to produce arabogalactan, a complex polysaccharide which resembles gum arabic in many respects. Arabogalactan is an odorless, colorless, water-soluble gum which is also a good source of galactose.

Production of the new gum requires a steeping process followed by concentration under reduced pressure and precipitation from ethyl alcohol. The material is purified by washing it with alcohol and low-boiling petroleum ether and is dried under vacuum. Between 7 and 17 per cent crude arabogalactan—based on the oven-dry weight of wood—is obtained by this process.

The waste remaining after the gum extraction can be used for fuel, pulp, or for other purposes. The Western Pine Association is now supplying research quantities of arabogalactan for trade evaluation. (CW, 7-28-51, p. 21; C&EN, 5-12-52, p. 1980)

Guayule Rubber Production

Guayule rubber has now been produced which is in every respect the equal of Malayan plantation rubber. It has been found that the freshly harvested shrub can be successfully processed for recovering its rubber without the use of chemical coagulants. The latex is coagulated by parboiling and mechanical treatment, although more experimentation is necessary before the most efficient method is established. Mill yields of rubber from the freshly harvested latex are generally high, but the method of preparing the shrub influences the recovery of the rubber hydrocarbon. When the shrub is conditioned and stored under conventional conditions of large-scale operation, the yield of rubber hydrocarbon decreases with increasing storage time. (CD, 4-52, pp. 11-12; Industrial and Engineering Chemistry, 1952, pp. 879-82)
West African Plant Gums

Two African plants have been investigated recently as possible sources of gum. *Anogeissus schimperi* exudes a water-soluble gum similar to mesquite gum. The aqueous solution of the gum is levorotary and does not reduce Fehling's solution. Hydrolysis and cleavage liberate arabinose, galactose, and glucuronic acid. *Khaya grandifolia* yields a gum which, upon hydrolysis, gives galactose and a degraded polysaccharide composed of galactose, rhamnose, and galacturonic acid. This gum resembles that of slippery elm. (Chemical Society Journal, 5-52, pp. 1918-19)

IV. NAVAL STORES

Market Developments--Figure 3, Figure 6, Table III

The year 1952 saw gradually decreasing prices for spirits of turpentine and wood turpentine during the first part of the year. Demand and production were both very slow; it was not until the latter part of the summer that the market improved enough to increase prices slightly. Toward the end of the year prices of the turpentines again fell off as a result of decreasing demand.

Gum turpentine production during the first half of the 1952-53 crop year was nearly 11 per cent less than the comparatively small production during the same period last season. Wood turpentine production during this season was 18 per cent less than production during the corresponding season last year. The total turpentine output was down 15 per cent from the same period of last year; gum turpentine accounted for 46.9 per cent of the total output, steam-distilled for 25.4 per cent, sulphate for 27.3 per cent, and destructively distilled for 0.4 per cent.

Prices of rosins started to decline in November, 1951, and reached their low points in early September of this year. Since then, a small increase in prices has been holding steadily. The greater part of the gum rosin stocks is in the Government's hands under the Department of Agriculture's loan program, and, if the Government continues to hold these stocks, prices should remain steady, with the possibility of small advances as the season ends, if demand increases further. However, one difficulty faced by the gum rosin industry is that, while the Government has large holdings of rosin under the loan, it is difficult to obtain gum rosin bagged for immediate shipment. This discourages many buyers. Business in wood rosin has been brisk recently, however, and some producers may have to increase production.

Gum rosin production has been declining since about 1939, although the production of wood rosin has been going up; the highest production was in the 1950-51 year (1,340,000 drums). This year, with a decline in demand, producers have reduced production and will probably produce less than 1,100,000 drums. Production of both gum and wood rosins has been lower this year and although wood rosin production during the next few
months will probably improve, it will probably not be enough to counteract the decreased production earlier in the year.

Dipentene and pine oil have been scarce because wood turpentine and rosin production has decreased and because the metal refining industries have increased their consumption of pine oil for recovering scarce metals from low-grade ores.

Export controls on most kinds of naval stores have been dropped by the Office of International Trade. Only pine oil and pine tar will remain under export license. It is hoped that the removal of export controls on rosin and turpentine will encourage more exports and thereby stiffen the market in the United States.

The German demand for rosin is strong and has been stimulated by the establishment of new enterprises in the paper industry; turpentine, however, is meeting competition from cheaper mineral-oil products. A petroleum distillate is being widely used in the paint and varnish industry and is reported to have cut into the turpentine market substantially.

The consumption of naval stores, especially pine oil, by the Canadian mining industry has been increasing during recent years and is expected to continue at a high rate. Most of Canada's imports of naval stores come from the United States.

New Zealand's rosin requirements, generally stable at 1,050 to 1,100 long tons per year, are virtually all imported from the United States. Turpentine, however, is under import restriction and, while largely obtained from this country previously, is being purchased to an increasing degree from Portugal. The shift has been blamed on monetary exchange difficulties. Australia has been generally dependent on imports for naval stores, with Sweden supplying most of the turpentine and the United States most of the rosin. Exchange difficulties have also been a problem there.

Rosin consumption in Brazil is expected to increase about ten per cent annually if the expansion of industries using this material continues. Imports are expected to total 34,000 metric tons for 1952, which, with accumulated inventories, will meet industrial requirements. The United States has supplied about 90 per cent of Brazil's annual rosin imports for many years and is expected to maintain this position in spite of more stringent Brazilian licensing regulations and the larger imports scheduled from France under a trade agreement with that country.

New Technical Developments

Dichloroethane Extraction of Rosin from Wood Stumps

It has been found that dichloroethane is a much better solvent than gasoline for the extraction of rosin and turpentine from residual tree stumps that were left in the ground for several years after cutting
the trees. By repeated extraction it is possible to remove over 90 per cent of the resinous content of the wood. (Izvest. Akad. Nauk Beloruss. S.S.R., 1948, No. 4, pp. 103-18)

**Maleo-pimaric Acid from Pine Gum**

A fairly simple process for producing maleo-pimaric acid from pine gum has been described. The crude pine gum is diluted with turpentine and filtered. After the removal of water, the cleaned gum is reacted with maleic anhydride at a moderate temperature. On cooling, a crystalline addition product separates and is removed by centrifuging.

Pilot-plant work indicates that the gum naval stores industry would have little difficulty in making the acid for commercial use. In printing inks the acid produces more brilliant and more workable azo pigments than the maleic-modified rosin now used. Good results have been obtained in using maleo-pimaric esters to plasticize polyvinyl chloride. The plasticizer, although not equal to the high-priced sebacates in performance, is able to compete with them on a cost basis. The acid soap has been used satisfactorily as an emulsifier in synthetic rubber production. (CE, 2-52, pp. 199, 201)

**Method of Improved Pine Gum Distillation**

Gum spirits of turpentine with improved color and very low acidity are produced in the distillation of pine gum by employing a section packed with glass fibers in the vapor line of the still. This packing lowers not only the water-insoluble acid content of the turpentine but also the water-soluble portion as well. (U. S. Patent 2,598,684)

**Terpene Hydroperoxides from Turpentine**

It has been found that gum turpentine yields certain terpene hydroperoxides which are particularly suitable for use as catalysts in producing cold rubber (synthetic rubber made at relatively low temperatures to produce an unusually high quality product). The most promising of these are pinane hydroperoxide and menthane hydroperoxide.

The production of terpene hydroperoxides from gum turpentine requires no unusual equipment and is not complicated. Only two steps are required to make pinane hydroperoxide in concentrations of 50 per cent, which is the catalyst strength now commonly used in the production of cold rubber. The naturally occurring unsaturated pinenes in turpentine are first catalytically hydrogenated to pinane—a process which can be carried out in the same kind of equipment, by the same procedures, and with the same catalyst used for the production of hydrogenated cottonseed oil for oleomargarine and shortenings. The pinane thus obtained is oxidized with gaseous oxygen (or air) to yield pinane hydroperoxide. When gum turpentine is used to produce menthane hydroperoxide, an additional step is required—the turpentine must be isomerized to monocyclic hydrocarbons before the hydrogenation step.
The commercial production of these new chemicals, using gum turpentine as the raw material, would open a large new market to the gum naval stores industry, which needs expanded outlets. At the same time, the use of gum turpentine for this purpose would help to conserve the short supply of benzene, the raw material for today's most widely used catalyst for cold rubber. (APJ, 2-18-52, p. 80; CW, 2-23-52, p. 31)

Testing Methods for Rosin Oils

The term "rosin oil" includes the oils obtained by the dry destructive distillation of rosin and certain compounded oils prepared from a rosin oil base, but it has no relation to the product formerly known as liquid rosin which is now called tall oil. The methods of testing, to determine the suitability of a rosin oil for any specific purpose, include measurements of color, specific gravity, viscosity, acid value, volatile matter content, water content, ash content, and mineral-oil content. (Proceedings of the American Society for Testing Materials, 1949, pp. 469-71)

Turpentine-Based Lubricant

A high-quality synthetic lubricant, which may be used in place of castor oil derivatives, has been made from turpentine. The lubricant is composed of the synthetic esters produced from certain dibasic acids; pinic acid, apparently the most important of these, may supplant other acids because of its greater availability. The diesters formed from the dibasic acids are suitable for lubricating fluids or can be combined with a gelling material to form greases. (PM, 11-52, p. 404; BW, 6-21-52, pp. 45-46)

New Uses for Tall Oil

Tall oil is beginning to be widely used in the organic coatings industry. The fatty acid calcium soaps and the esters made from tall oil can be used to advantage in lacquer and paint formulations. The largest single use of tall oil in the coatings industry is in the production of tall-oil-modified phthalic alkyds. Tall oil can also be used as a very low cost filtration agent; such an agent has possible applications for recovering the valuable but highly dilute constituents of industrial wastes which have been too expensive to extract. It has an important potential use in the recovery of minerals from low-grade ores. (NSR, 11-15-52, pp. 16-18; CD, 11-52, pp. 4-5)
V. APPENDIX
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The complete list of periodicals scanned in this survey follows. The abbreviations used in this report appear after the name of each journal. All journals were surveyed for the period January 1, 1952, through December 31, 1952.

American Paint Journal (APJ)

American Perfumer and Essential Oil Review (AP&EO)

Business Week (BW)

Chemical and Engineering News (C&EN)

Chemical Engineering (CE)

Chemical Week (CW)

Chemurgic Digest (CD)

Drug and Cosmetic Industry (D&CI)

Economic Botany (EB)

Foreign Commerce Weekly (FCW)

Journal of the American Oil Chemists' Society (JAOCS)

Naval Stores Review (NSR)

Oil, Paint and Drug Reporter (OP&DR)

Paint Manufacturer (PM)

Paint, Oil and Chemical Review (PO&CR)

Science News Letter (SNL)

Soap and Sanitary Chemicals (S&SC)

Textile Technology Digest (TTD)

Tung World (TW)

Periodical indexes examined in the survey were:

The Agricultural Index (January—November, 1952)

Chemical Abstracts (January 10, 1952—December 25, 1952)

The Industrial Arts Index (January—November, 1952)
The International Index to Periodicals (January–November, 1952)

Reader's Guide to Periodical Literature (January–November, 1952)
Figure 1. Weekly Price Trends of Vegetable Waxes.
Figure 2. Weekly Price Trends of Vegetable Gums and Resins.
Figure 3. Weekly Price Trends of Naval Stores.
Figure 4. Monthly Imports of Vegetable Waxes.
Figure 5. Monthly Imports of Vegetable Gums and Resins.
Figure 5. Monthly Imports of Vegetable Gums and Resins. (Second
Figure 5. Monthly Imports of Vegetable Gums and Resins. (Third Page)
Figure 6. Monthly Production of Naval Stores in the United States, January-November, 1952.
TABLE I

MONTHLY IMPORTS OF VEGETABLE WAXES
(January--September, 1952)
(Thousands of Pounds)

<table>
<thead>
<tr>
<th>Month</th>
<th>Carnauba</th>
<th>Candelilla</th>
<th>Ouricuri</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>1,563</td>
<td>819</td>
<td>121.9</td>
<td>46.7</td>
</tr>
<tr>
<td>February</td>
<td>1,844</td>
<td>783</td>
<td>206.8</td>
<td>271.8</td>
</tr>
<tr>
<td>March</td>
<td>782</td>
<td>597</td>
<td>116.6</td>
<td>296.8</td>
</tr>
<tr>
<td>April</td>
<td>1,528</td>
<td>37.3</td>
<td>251.7</td>
<td>182.5</td>
</tr>
<tr>
<td>May</td>
<td>2,016</td>
<td>38.0</td>
<td>95.2</td>
<td>14.3</td>
</tr>
<tr>
<td>June</td>
<td>1,571</td>
<td>378.3</td>
<td>211.4</td>
<td>759.</td>
</tr>
<tr>
<td>July</td>
<td>1,302</td>
<td>51.6</td>
<td>296.</td>
<td>263.</td>
</tr>
<tr>
<td>August</td>
<td>2,051</td>
<td>480</td>
<td>82.8</td>
<td>346.7</td>
</tr>
<tr>
<td>September</td>
<td>985.5</td>
<td>34.7</td>
<td>311.4</td>
<td>144.</td>
</tr>
</tbody>
</table>

1 Data obtained from United States Imports of Merchandise for Consumption, United States Department of Commerce Report FT-110, Washington, D. C.
# TABLE II

MONTHLY IMPORTS OF VEGETABLE GUMS AND RESINS
(January—September, 1952)
(Thousands of Pounds)

<table>
<thead>
<tr>
<th>Month</th>
<th>Agar</th>
<th>Gum Arabic</th>
<th>Gum Benzoin</th>
<th>Damar</th>
</tr>
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<tbody>
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<td>January</td>
<td>26.4</td>
<td>1,319</td>
<td>--</td>
<td>287.1</td>
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<td>February</td>
<td>27.0</td>
<td>704</td>
<td>--</td>
<td>103.4</td>
</tr>
<tr>
<td>March</td>
<td>12.8</td>
<td>1,183</td>
<td>--</td>
<td>143.8</td>
</tr>
<tr>
<td>April</td>
<td>20.0</td>
<td>1,064.6</td>
<td>--</td>
<td>289.7</td>
</tr>
<tr>
<td>May</td>
<td>53.0</td>
<td>1,739</td>
<td>--</td>
<td>303.3</td>
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<tr>
<td>June</td>
<td>14.9</td>
<td>1,337</td>
<td>--</td>
<td>352.2</td>
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<tr>
<td>July</td>
<td>41.8</td>
<td>1,512</td>
<td>--</td>
<td>166.0</td>
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<td>August</td>
<td>28.1</td>
<td>1,865</td>
<td>--</td>
<td>248.1</td>
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<td>September</td>
<td>45.3</td>
<td>1,178</td>
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<td>338.5</td>
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</tbody>
</table>

<table>
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<tr>
<th>Karaya Gum</th>
<th>Kauri Gum</th>
<th>Gum Tragasol</th>
<th>Gum Mastic</th>
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</thead>
<tbody>
<tr>
<td>January</td>
<td>536.4</td>
<td>--</td>
<td>716.6</td>
</tr>
<tr>
<td>February</td>
<td>635.8</td>
<td>11.3</td>
<td>501.8</td>
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<tr>
<td>March</td>
<td>770.9</td>
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<td>573.5</td>
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<tr>
<td>April</td>
<td>661.5</td>
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Data obtained from United States Imports of Merchandise For Consumption, United States Department of Commerce Report FT-110, Washington, D. C.
### TABLE III

MONTHLY PRODUCTION OF NAVAL STORES IN THE UNITED STATES

(January--November, 1952)

<table>
<thead>
<tr>
<th>Month</th>
<th>Gum Turpentine (50-gal. bbls.)</th>
<th>Gum Rosin (520-lb. drums)</th>
<th>Wood Turpentine (50-gal. bbls.)</th>
<th>Wood Rosin (520-lb. drums)</th>
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<td>8,360</td>
<td>31,720</td>
<td>35,820</td>
<td>110,900</td>
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<tr>
<td>February</td>
<td>5,150</td>
<td>17,890</td>
<td>34,240</td>
<td>108,320</td>
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<tr>
<td>March</td>
<td>6,490</td>
<td>18,780</td>
<td>36,330</td>
<td>102,050</td>
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<tr>
<td>April</td>
<td>16,970</td>
<td>44,660</td>
<td>35,920</td>
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<td>May</td>
<td>26,740</td>
<td>70,580</td>
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<td>June</td>
<td>28,770</td>
<td>76,010</td>
<td>29,320</td>
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<td>July</td>
<td>31,800</td>
<td>88,010</td>
<td>24,470</td>
<td>76,840</td>
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<td>August</td>
<td>25,620</td>
<td>72,430</td>
<td>25,970</td>
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<td>September</td>
<td>21,200</td>
<td>60,690</td>
<td>26,970</td>
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<td>17,690</td>
<td>54,960</td>
<td>29,700</td>
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<td>November</td>
<td>15,160</td>
<td>57,410</td>
<td>29,400</td>
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<table>
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<th>Month</th>
<th>Dipentene (50-gal. bbls.)</th>
<th>Pine Oil (520-lb. drums)</th>
<th>Pine Tar (50-gal. bbls.)</th>
<th>Other Hydrocarbons (50-gal. bbls.)</th>
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<td>15,330</td>
<td>10,780</td>
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<tr>
<td>February</td>
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<td>7,820</td>
<td>2,480</td>
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<td>3,360</td>
<td>12,260</td>
<td>7,950</td>
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1 Data obtained from Bureau of Agriculture Economics statistics published in Naval Stores Review.
SURVEY OF THE NEEDS OF INDUSTRY FOR RAW MATERIALS FROM NEW PLANTS TO BE GROWN IN THE UNITED STATES

By

H. H. SINEATH, P. M. DAUGHERTY, R. N. HUTTON, III and T. A. WASTLER, JR.

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CONTRACT NO. A-IS-33685

DIVISION OF PLANT EXPLORATION AND INTRODUCTION
BUREAU OF PLANT INDUSTRY
UNITED STATES DEPARTMENT OF AGRICULTURE

- o - o - o - o -

JUNE 5, 1953
ENGINEERING EXPERIMENT STATION
of the Georgia Institute of Technology
Atlanta, Georgia

PHASE REPORT NO. 3
PROJECT NO. 177-170

SURVEY OF THE NEEDS OF INDUSTRY
FOR
RAW MATERIALS FROM NEW PLANTS
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By
H. H. SINEATH, P. M. DAUGHERTY,
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CONTRACT NO. A-18-33685

DIVISION OF PLANT EXPLORATION AND INTRODUCTION
BUREAU OF PLANT INDUSTRY
UNITED STATES DEPARTMENT OF AGRICULTURE

- o - o - o - o -

JUNE 5, 1953
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C. Properties of Bamboos

1. Composition
   a. Cellulosic Constituents
   b. Noncellulosic Products

2. Physical Properties

D. Potentialities of Bamboos

1. Areas in Which Bamboos May Be Grown

2. Uses in the United States Compared to Uses in Other Countries
   a. Concrete Reinforcement
   b. Paper Pulp

(1) Species of Bamboo Suitable for Paper Pulp
   (1.1) India
   (1.2) China and Japan
   (1.3) Africa
   (1.4) South America
   (1.5) Philippines
   (1.6) United States

(2) Sizes of Fibers Obtained from Various Species

(3) Various Pulping Processes
   (3.1) Mechanical Pulping
   (3.2) Soda Process
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Phase Report No. 3, Project No. 177-170

I. SUMMARY

This report presents the information obtained from literature and market surveys conducted on bamboos, candelilla, and Simmondsia chinensis to determine the industrial potential of these plants and their products in the United States. The particular plants were selected for more detailed study from the results of the information obtained in a preliminary survey conducted in 1951 on the needs of industry in the United States for raw materials obtained from plant sources.

Background material was obtained on each item by comprehensive coverage of selected literature. Contacts were made by correspondence with representatives of government laboratories, experiment stations, industrial associations, research institutes, and industrial concerns which could be reasonably assumed to use, or to be potential users of, products derived from the selected plants. Individuals who were known to be interested in these plants were also contacted. Personal interviews were arranged when the correspondence indicated that they would be desirable.

The methods used have been considered satisfactory for determining the required information. The results obtained and the conclusions and recommendations are presented in detail for each plant. Extensive bibliographies for each subject were compiled and are presented in the Appendix.
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II. INTRODUCTION

From the information obtained in a preliminary survey, conducted in 1951 at the Georgia Institute of Technology, on the needs of raw materials from plant sources, three plants were selected for more detailed study by the Division of Plant Exploration and Introduction of the Bureau of Plant Industry of the United States Department of Agriculture. Extensive literature reviews and market surveys were made on bamboo, candelilla, and Simmondsia chinensis. The programs were arranged to obtain as much information as possible concerning the history and growth characteristics of each of the plants, and the past, present, and future market potentials of the established and possible future products derived from each of these plants. In general, each of these plants possesses enough potentialities to justify certain experimental programs. These programs would be very desirable assets in the successful development of these plants as domestic crops.
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III. PROCEDURE

The following indexes and abstract indexes, which were thought to contain references to pertinent information, were scanned under those headings which would lead to articles of interest:

- Agricultural Index
- Bibliography of Agriculture
- Biological Abstracts
- British Abstracts*
- Chemical Abstracts
- Engineering Index
- Experiment Station Record
- International Index to Periodicals
- Industrial Arts Index
- Readers' Guide to Periodical Literature

Those periodicals which were scanned in connection with phase two of the 1951 preliminary survey and phase one of this project were also read for items of interest.

Although no attempt was made to exhaust the patent literature, the Official Gazette was checked under several headings for each item. It was found that most of the references obtained in this way were duplicated in the secondary sources.

Published bibliographies on these subjects were also consulted, as well as those bibliographies which were compiled and made available by industrial concerns and individuals interested in these plants or products obtained from them.

The secondary references were covered from either the initial date of publication or from a later date determined by the original mention of the plant in the literature, i.e., about 1900 for candelilla and 1790 for Simmondsia. The original references were obtained and scrutinized when they contained information of value to the surveys.

Libraries of United States educational institutions that had graduate programs in fields in which research might possibly have been conducted with bamboos, candelilla, or Simmondsia lent copies of those theses or dissertations available. In addition, the card files of the United States Department of Agriculture Library in Washington were reviewed and references therein were consulted.

Import statistics were obtained from United States Imports of Merchandise for Consumption, United States Department of Commerce Report FT-110, unless otherwise stated.

Correspondence was directed to organizations which were known, or which could be assumed, to have an interest in the selected plants or products derived from them. Included were representatives of experiment stations, government laboratories, research institutes, industrial associations, and industrial concerns. These were chosen from contacts made in connection with the preliminary survey of 1951 as well as from the published listings of such organizations. Individuals who were interested in the selected plants or their products were contacted when their names...
were encountered either through the correspondence or the literature. From the original correspondence sent out, answers were received from approximately 78 per cent. Additional correspondence was required in some cases, and personal interviews were arranged in instances where it appeared that they would be desirable.

Table XXV, which is included as Appendix I, presents a selected list of companies and individuals who have expressed interest in the possible development of these plants or products from these plants. It also contains comments concerning the specific applications that are of interest to them.

The information obtained from all sources consulted is presented in individual chapters:

IV. Candelilla
V. Simmondsia chinensis
VI. The Bamboos

References cited for each of these items are presented at the end of each section. Extensive bibliographies, which are believed to be the most comprehensive compiled to date on these subjects, are presented in the Appendixes III, IV, and V.
IV. CANDELILLA

A. Introduction

Candelilla wax occurs as a coating on a weed that is native to northern Mexico and parts of Texas. Only minor attempts have been made to utilize this wax source in the United States, although in Mexico candelilla wax production is a relatively important industry. Practically all known commercial production originates in the states of Coahuila, Nuevo Leon, Durango, Zacatecas, San Luis Potosi, and Chihuahua, and the product is distributed through an organization designed to sell collectively all the wax produced. This organization functions under the sanction of the Banco Nacional de Comercio Exterior, through which the sales are made. This arrangement serves to establish the price of the wax, to control the quality and markets, and to improve the conditions of the workers who collect the wax. (48, 91)

The plant as exploited grows wild, and no attempts at cultivation in Mexico have been recorded, although there are advocates who feel that, in order to keep production equal to the demand, cultivation must be undertaken eventually. There have been some controls exercised to restrict overharvesting of the areas of candelilla growth, but it is felt that the number of available candelilla plants is diminishing. (8, 39, 40) Some attempts to grow the plants in the United States, Haiti, and Santo Domingo (Dominican Republic) were apparently not very successful. (18, 55, 92) However, a representative of the Haiti Department of Agriculture has stated that at least one species of the plant is doing well in Haiti. (73)

The small amount of candelilla wax produced in the United States originates from the Big Bend region of Texas. The Texas production of
wax is sporadic; the production is increased when the price is high (i.e.,
during times when the world is at war) and practically nil when the price
becomes "normal." (59) The production in Texas is limited also by the
fact that most of the candelilla plants grow within the Big Bend National
Park and are not available to the wax producers. (18, 23)

The importance of candelilla wax in this country is reflected in
the fact that approximately seven and a half million pounds have been
imported annually for a number of years. Carnauba wax is the only vege-
table wax that is imported in larger amounts. Candelilla wax is consumed
in relatively large amounts in the production of polishing materials and
chewing gum. This wax has also been utilized in the preparation of thermo-
plastic compositions for casting patterns and for numerous other uses.

B. Candelilla Plants

1. Botanical Description

Candelilla wax is obtained from the plants known as "candelilla,"
[Euphorbia cerifera Alcacer, or E. antisypilitica Zucc.--Standley (83)
considers these to be probably identical, although others do not share this
belief (67)] and "jumete," [Pedilanthus pavonis (Klotzsch and Garcke)
Boiss., and P. aphyllus Boiss.]. "Jumete" reportedly yields only a minor
amount of wax. The plants are members of the family Euphorbiaceae and
occur as bunches of reedlike stems, approximately two to five feet high
and one-quarter to one-half inch thick. The leaves are remote and dis-
tinct and are soon deciduous. The stems have a bluish-green color and
are coated with a thin film of the wax, which sometimes appears as hair-
like rods. Since this wax is on the surface, rough handling, particularly
if the plants are dry, causes some of the wax to fall off and be lost.
The fact that some wax is found in the outer cells of the stem accounts for the fact that only a 1.5 to 2 per cent yield of wax is realized in commercial operation, whereas laboratory examination shows the wax content to be 3 to 5 per cent. (5, 38, 45, 48, 50, 53, 54, 56, 57, 60, 71, 72, 79, 83, 88, 91)

The plants grow in arid regions where other useful plants cannot survive because the annual rainfall is low. This would indicate that candelilla could serve well as a crop for regions which are not being utilized at the present time. The plant grows to a larger size and produces more luxuriant foliage in areas where there is abundant water, but in such areas it produces little or no wax. This is because the wax coating is secreted as a protective measure to prevent the evaporation of the plant's moisture. This is also why the percentage of wax in the plants is higher in the dry winter months. It has been reported that candelilla grows and produces wax well in regions where the annual rainfall is less than four inches; however, the plant itself thrives in areas where the rainfall is up to 20 inches and grows best where the rainfall is between 8 and 12 inches. The optimum conditions for growth of plants of commercial value (proper balance between growth and wax-producing ability) have not yet been determined. Plots of candelilla plants grown under controlled conditions should serve well to establish the most practical conditions for commercially valuable plants. (29, 38, 45, 46, 75, 92)

Wild candelilla grows on well-drained slopes of rocky, sandy soil that is poor in humus; the plants are rarely found in valleys or lowlands. Better types of soil evidently have the same effect as abundant
moisture, producing better plant growth and lower wax yields. (29, 38, 57, 75)

The yield per acre of candelilla plants in the wild state varies considerably, but it has been reported that a 10-ton per acre yield is not uncommon in some areas. Assuming that a recovery of two per cent wax could be realized, this would mean a wax yield of 400 pounds from such an acre. (14, 16)

2. Exhaustion of Wild Candelilla Plants

There are vast areas of candelilla growth that have not been used because the production of wax requires quantities of water, and the drilling of wells in, or transporting water to, these areas is not practical. Also, the rough terrain in which some candelilla grows makes obtaining it prohibitive. However, the available areas of candelilla wax production are becoming exhausted. Excessive harvesting of the plants because of a good demand for the wax occurs at times. The workers are inclined to pull all the plants from an area before moving on, and most harvesting is done during the winter months when the pieces of plant material left in the ground have less chance of surviving. The Mexican control organization felt that the intensive harvesting of the available candelilla plants during the war years so depleted the supply that they prohibited production of the wax from July, 1947, to August, 1948. (8, 39)

3. Cultivation

There are no records of any attempt to produce candelilla wax by cultivation in Mexico. However, some attempts have been made to grow candelilla in this country (Texas and Arizona) and in Haiti and Cuba.
These plantings were all sponsored by American concerns. Little success was realized in these attempts for undetermined reasons. (No publication concerning the plantings in Texas, Haiti, and Cuba could be found.) Several small plots consisting of only a few specimens have also been planted in various places in this country by individuals and botanical gardens. Reports on the smaller plots indicate that the plant grows well under cultivation but has an appreciably lower wax content than does the wild plant. It would seem that, in all probability, considering the previously stated effects of soil and moisture upon the growth of the plant and the wax content, the plants were not grown under the optimum conditions. (18, 36, 39, 51, 74, 86, 92, 93)

In the natural state, the plant reproduces from root material and from seeds. The experimental plantings that have been made were propagated by means of the root material since the collection of the seed has been impractical. The seeds are small and the seed pods burst at maturity, scattering the seeds. However, it has been suggested that the use of seeds would probably be the most satisfactory method of starting a large-scale planting. Root material does not survive for long periods of time after being removed from the ground, and so a considerable amount of the material planted in this way does not survive. The collection of the seeds would be expensive and would require workers to spend considerable time in the regions of growth of wild candelilla. The initial authentication of the plants from which the seeds are to be obtained would also present a problem. (From the sketchy data of Tables I through V it would appear that the species E. antisypilloitica would be of greatest commercial value because of the higher melting point and saponification
number.) There would also be technical difficulties connected with the growing of plants from seed in poor lands. Extra water might have to be provided to start germination of the seed and to assist early growth, and there would have to be water available for processing the plants to obtain the wax; the requirements would depend upon the method of extraction used. In order for the plants to produce sufficient wax to be commercially profitable, these plantings would have to be in naturally arid regions. Another difficulty is the two to five years it takes the plants to grow and produce commercial quantities of wax. (23, 46, 93)

The cultivation may not prove to be exceedingly difficult since it is known that a large number of wild plants reproduce from seed without any attention. The plant possesses excellent drought-resistant qualities and does not appear to be susceptible to diseases. Goats and hares cause some damage to wild candelilla by eating the foliage, but this should present no serious problem for cultivated material. The best method of planting would have to be determined by experiments; however, it would seem that compact spacing would be required since the percentage of available wax in the plant material is low. Approximately 50 tons of plant material are required to produce a ton of wax. More efficient methods of obtaining the wax could reduce this required volume of raw material. (Actually, only about two per cent wax is recovered by the present method and the plant contains about three to five per cent wax.) It would seem that the handling of the planting would require little or no labor except for the preparation of the land, the planting, and the harvesting of the mature plants.
The most efficient and practical method of harvesting the plants would also have to be worked out by trial. The Mexican method of hand harvesting does not seem to be practical in the United States unless the labor could be provided by Mexican laborers. Since mechanical cutting of the plants results in the destruction of the root system, it would appear that this method could not be used. However, since candelilla in the wild does reproduce by seeds, it might be possible to use a mowing-type machine, provided the plant growth is dense, and use a strip-method of cutting. For example, if a four-year maturing period were determined as the most efficient for commercial growing, a narrow strip would be cut and a strip three times as wide left unharvested. The next year an adjoining narrow strip would be harvested. In this manner, after the planting has been established, the harvested area would always be adjacent to a mature, seed-producing area. If the cut plants died they would be replaced by plants propagated by the seeds from the nearby mature plants. Another possibility would be to devise a method of preventing the so-called "bleeding" of the root systems. This might be accomplished by planting the candelilla in rows, cutting and then plowing soil over the stubble; whether or not this would accomplish the desired effect would, of course, have to be determined.

There is also the possibility that supplying quantities of water to the cut-over areas immediately after harvesting and for a long enough time thereafter might prevent the death of the root material. However, the fact that the planting would probably be made in areas of limited water supply might make such a procedure impractical.
No estimates were available as to what weight of candelilla could be grown under cultivation per acre of land. It has been reported that wild candelilla areas yield up to ten tons per acre, and it is likely that more could be grown under cultivation. (14, 16) The quantity that could be realized would have to be established by controlled trial plantings. These plantings should be planned to establish which species yields the wax of greatest commercial value.

4. Harvesting Techniques

The exploitation of candelilla is most extensive in the winter months; labor is generally more readily available since other agricultural activities are suspended, and the wax content of the plants is highest at this season. The candelilla plants are normally harvested by laborers who either pull the plants from the ground by hand or dig them with a tool resembling a small spading fork. The root does not contain any wax, but in order to keep the plant tops from falling apart, the crowns are removed intact. A large number of the plants do not sprout again after such treatment during dry seasons; therefore, the harvesting in dry winter months results in the gradual exhaustion of candelilla plants. It has been reported that if there is sufficient moisture, new sprouts will appear from the pieces of root material remaining in the ground, and the plants will re-establish themselves fairly rapidly, maturing enough for another harvest in two to five years. The plants also reproduce from diminutive seeds, and since some plants grow in high, inaccessible places, the seeds from these plants gradually replenish lower areas which have been overworked. This method of reproduction is necessarily very slow. (29, 39, 57, 59)
In Texas, experimentation on harvesting the plants using a small bulldozer mounted on a light caterpillar tractor was conducted by one company. With this machine, clumps of brush containing the candelilla plant were pushed from the ground and the candelilla plants picked out from the other plants later. (59, 92)

Another United States firm, cooperating with a power company in the Presidio, Texas, area, experimented with a method of cutting candelilla mechanically, which would have been faster and cheaper than hand harvesting. It was hoped that the plants would not die out since, by this method, the entire root system would be left in the ground. However, this did not prove to be the case as the plant "bleeds" and the root dies. The Mexican government has forbidden harvesting by cutting the shoots for this reason. (83, 91)

C. Candelilla Wax

1. Extraction Methods

Little improvement has been made in the methods used for extraction of the wax of the candelilla plant. The most primitive method of boiling the plant in tanks over open fires with water containing sulfuric acid has been the most feasible. This is because the producing areas are scattered, and the yield of wax per plant is low. An effective area of operation is soon depleted of plants, and the extraction equipment must be disassembled and moved. The extraction procedure calls for filling a tank or basin with whole candelilla plants and covering the plants with water. The tank of material is then heated to boiling over a direct fire (usually the fuel used for this fire is spent candelilla plants that have been dried in the sun), and eight kilograms of sulfuric acid are added for each 100 kilograms of candelilla plants. A metal grid is used to keep the
plants submerged and to facilitate the removal of the wax, which floats
to the surface as a dark scum. This scum is carefully skimmed and trans-
ferred to another container in which it is again treated by boiling with
sulfuric acid. The wax is then allowed to solidify, the water layer is
drawn off from the bottom, and the wax cake removed from the drum. The
center layer of the cake is cut out and shipped to refiners. The top and
bottom portions, which contain a high percentage of foreign matter, are
thrown back into the tank with the next charge. The crude wax obtained,
still containing about 10 per cent impurities including dirt, water, and
pieces of plant material, represents about two per cent of the weight of
the plant material used. For small-scale producers, this is the lowest
limit of yield at which exploitation is profitable. Large-scale produc-
ers can operate profitably at a crude yield of about 1.75 per cent. (4,
5, 6, 15, 17, 20, 21, 27, 28, 38, 53, 60, 83, 85, 88, 91)

For commercial use the wax is further purified to remove the dirt
and most of the water present. This final purification of the crude wax
is usually carried out, not in the field, but at collection stations. The
raw wax has a grey-white appearance, and after the water is removed by
further treatment with sulfuric acid the color is that of "café au lait."
(29, 38) The sole criterion for degree of purity is the color, judged
by the comparison with a standard block of wax.

A modification of the above procedure, which is not often practiced,
utilizes steam pipes to heat the tank rather than direct fire. This
method presents the disadvantage of requiring heavy equipment, which is
unsuitable to the transient nature of the industry. The procedure is
essentially the same as in the first method except that common salt is
added in the first purification step. (28, 38, 57, 90)
Extraction with solvents gives good results, the procedure being varied depending upon the solvent used. The principle, however, is always the same. The hot solvent vapors are kept in continuous contact with the wax-bearing material and allowed to condense, carrying the wax away from the plant material. The process is continued until no color is detectable in the condensing solvent, indicating that no more wax is being extracted. The wax obtained by this method contains considerable resin, which is separated by means of a centrifugal apparatus and extracted from the wax with alcohol. Solvent extraction should be less costly and should result in higher yields of wax recovery; however, the large initial outlay for equipment and the previously mentioned dispersed areas of growth of candelilla have hindered the progress of utilizing this method. (6, 20, 38, 44, 57, 68, 81)

An early patent was issued for a process for recovering the wax from the candelilla plant. This process consisted of subjecting the plants to dry heat of approximately 300° F. to convert the moisture of the plant to steam for expelling the wax and then passing hot steam through the mass of material to carry out the adhering wax. Evidently the process does not produce the results claimed and so has not been used. (38, 89)

Another patent was issued in 1929 for a method of mechanical removal of the wax by subjecting the plants to crushing, tearing, and beating. The plant fiber was screened from the finely divided wax and nonwaxy portions prior to extraction. (37) Other work on mechanical brushing of the plant stems to remove the wax proved to be impractical. (95)

Since the present candelilla wax industry is migratory in nature, and since there is a periodic relocation of the centers of production
because of the exhaustion of the raw materials in a given area, large investments in equipment are not feasible. An example of a large-scale processing plant that operated for a time and had to be abandoned is recorded. This plant, located on the "historic estate of Guadalupe" in Mexico, could treat two tons of candelilla per hour but was only able to operate practically so long as the raw material was abundantly available within a radius of not more than about six miles. (43)

If the plant were cultivated, a large centrally located processing plant might prove practical. One advantage of this type of operation is that more efficient use of byproducts is possible. For example, it has been reported that the spent candelilla plants are an acceptable source of paper pulp. (16, 17, 48)

2. Refining Methods

Several methods have been suggested for refining candelilla wax, in addition to the sulfuric acid treatment, in an attempt to decrease the resin content and to obtain a harder product. Claims are that candelilla wax of lower resin content could replace carnauba in many applications. Selective solvent extraction of the resins has been demonstrated, as has the destruction of the resin components by means of oxidation with peroxides, permanganate, and chromic acid. (63, 68, 70, 78, 88) The treatment of candelilla with organic acids at elevated temperatures to produce a harder, higher-melting material (75°C) has been patented. (87)

The control of the sales of candelilla wax in Mexico was established with the understanding that part of the resulting increased income to the producers would be applied to the much-needed scientific work on improvement of the quality of the wax. From the meager amount of published
information concerning the refining of candelilla, it is evident that little of this income has been expended for this purpose. (48)

3. Properties

The primitive method employed to recover candelilla wax, and the fact that other wax-bearing plants may be inadvertently gathered with the candelilla plants, results in the commercial wax's having varied chemical and physical characteristics. Another factor contributing to uncertain composition is that the wax plants harvested during the winter season yield a wax proven to be higher-melting and harder than the wax extracted from plants collected at other times. In addition, the wax obtained from the different members of the family Euphorbiaceae differs considerably in these properties. Also, plants of different ages yield waxes of different properties. The lack of consistent data on the properties of commercial candelilla wax is reflected in the fact that numerous standard reference tables of waxes either omit or say very little about this wax. (48, 49, 75) Tables I through V are compilations of the reported constants and the constituents of candelilla wax. The wax is soluble in organic solvents such acetone, benzene, carbon disulfide, carbon tetrachloride, chloroform, dekalin, ether, gasoline, and tetralin. The solubility of the wax in absolute alcohol is small; however, an alcohol-benzene (2-3) mixture is reportedly an excellent solvent. The fact that the resin components of candelilla wax are more soluble in alcohol than the wax makes alcohol a valuable solvent for purification. (1, 6, 20, 35, 44, 57, 67, 88)

4. Uses

Candelilla wax has been, and is, used for numerous purposes. These uses are summarized in Table VI.

-21-
## TABLE I

### CONSTANTS OF CANDELILLA WAX FROM

**Euphorbia antisyphilitica**

<table>
<thead>
<tr>
<th>Item</th>
<th>Reference 50</th>
<th>Reference 71</th>
<th>Reference 72</th>
<th>Reference 88</th>
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<tr>
<td>Melting Point, °C</td>
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<td>77.4</td>
<td>74-80, 77.4</td>
<td>77.2, 75.8-77.4</td>
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<td>Setting Point, °C</td>
<td>64.5</td>
<td>---</td>
<td>---</td>
<td>63.8-67.7</td>
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<td>Saponification Number</td>
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<td>104.11</td>
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<td>5.23, 5-6</td>
<td>5.9</td>
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<tr>
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<tr>
<td>Density at 15° C</td>
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<td>0.9473</td>
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<td>0.9807-0.9920</td>
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<tr>
<td>Refractive Index at 71° C</td>
<td>1.4555</td>
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<tr>
<td>Acidity</td>
<td>---</td>
<td>0.03</td>
<td>0.03, 0.32</td>
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<td>Fatty Acids (%)</td>
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<tr>
<td>Nonsaponifiables (%)</td>
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<td>Ash Content (%)</td>
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<td>Hardness Value (Shore Durometer)</td>
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(Continued)
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<th>Reference 71</th>
<th>Reference 72</th>
<th>Reference 88</th>
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<tbody>
<tr>
<td>Penetration Value at 25°C, No. 14 Needle, 5 sec., 100-gms. top wt.</td>
<td>---</td>
<td>---</td>
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<tr>
<td>Coefficient of Density Change per Degree C at 27°C-44.4°C</td>
<td>---</td>
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<td>---</td>
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<tr>
<td>Coefficient of Cubical Expansion</td>
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<td>0.00404(25°C)</td>
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<tr>
<td>Volume Decrease During Solidification (%)</td>
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<td>---</td>
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<td>11.80</td>
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</tbody>
</table>

a The ester of sitoserol (C_{29}H_{49}OH) and dihydroxymyricinoleic acid (C_{30}H_{62}O_4) constitutes about 20 per cent of the ester portion of the wax. Also present are esters of the normal acids and alcohols—C_{28}, C_{30}, C_{32}, and C_{34}. Some free resin acids are present as well as amounts of the above acids. (7, 19, 24, 76, 79, 88)

b These are data on refined wax.
<table>
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<th>Item</th>
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<th>Reference 38</th>
<th>Reference 45</th>
<th>Reference 75</th>
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<td>Melting Point, °C</td>
<td>80-85</td>
<td>75</td>
<td>--</td>
<td>65-69</td>
<td>68</td>
</tr>
<tr>
<td>Saponification Number a</td>
<td>35.0-86.5</td>
<td>35.0-36.5</td>
<td>35.0-36.5</td>
<td>46-65</td>
<td>60.7</td>
</tr>
<tr>
<td>Iodine Number</td>
<td>14.42-20.4</td>
<td>14.42-20.4</td>
<td>14.4-20.4</td>
<td>19-44</td>
<td>17.4</td>
</tr>
<tr>
<td>Acid Value</td>
<td>12.73-18.11</td>
<td>--</td>
<td>--</td>
<td>12-20</td>
<td>15.4</td>
</tr>
<tr>
<td>Density at 15° C</td>
<td>0.9820-</td>
<td>0.9320-</td>
<td>0.9320-</td>
<td>0.969-</td>
<td>0.9838</td>
</tr>
<tr>
<td></td>
<td>0.9856</td>
<td>0.9470</td>
<td>0.9626</td>
<td>(71°)</td>
<td></td>
</tr>
<tr>
<td>Refractive Index at 85° C</td>
<td>1.4545-</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>1.4626</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Acidity</td>
<td>--</td>
<td>0.003</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Fatty Acids (%)</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>29</td>
<td>--</td>
</tr>
<tr>
<td>Nonsaponifiables</td>
<td>76.7-77.27</td>
<td>76.7</td>
<td>--</td>
<td>74</td>
<td>--</td>
</tr>
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</table>

(Continued)
TABLE II (Continued)

CONSTANTS OF CANDELILLA WAX FROM Euphorbia cerifera

<table>
<thead>
<tr>
<th>Item</th>
<th>References 1 and 67</th>
<th>Reference 38</th>
<th>Reference 45</th>
<th>Reference 75</th>
<th>Reference 88</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrocarbons (%)b</td>
<td>42.49-45-52-70</td>
<td>--</td>
<td>45-52-70</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Moisture (%)</td>
<td>59.70</td>
<td>--</td>
<td>--</td>
<td>1.25</td>
<td>--</td>
</tr>
<tr>
<td>Reichert-Weissl Number</td>
<td>0.53-7.69</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

a The ester of sitosterol (C_{29}H_{49}OH) and dihydroxymyricinoleic acid (C_{30}H_{62}O_{4}) constitutes about 20 per cent of the ester portion of the wax. Also present are esters of the normal acids and alcohols—C_{28}, C_{30}, C_{32}, and C_{34}. Some free resin acids are present as well as amounts of the above acids. (7, 19, 24, 76, 79, 88)

b The hydrocarbons of the candelilla wax have been examined by several investigators who report the main hydrocarbon to be a normal C_{31} paraffin. Also present are C_{29} and C_{33} normal paraffins. (1, 7, 19, 24, 26, 35, 53, 57, 70, 76, 80, 88)
TABLE III

CONSTANTS OF CANDELILLA WAX FROM
Pedilanthus pavonis

<table>
<thead>
<tr>
<th>Item</th>
<th>References</th>
<th>Reference 53</th>
<th>Reference 68</th>
<th>Reference 88</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melting Point, °C</td>
<td>65-69&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>67-70</td>
<td>75.8-77.8</td>
<td>67.5</td>
</tr>
<tr>
<td></td>
<td>70-72</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Setting Point, °C</td>
<td>---</td>
<td>63-68</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Saponification Number</td>
<td>46-66</td>
<td>50-65</td>
<td>46.7-104.1</td>
<td>58.1</td>
</tr>
<tr>
<td>Iodine Number</td>
<td>15-36&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12-21</td>
<td>5.2-36.8</td>
<td>19.8</td>
</tr>
<tr>
<td></td>
<td>37&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acid Value</td>
<td>11-19,19.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>10-20</td>
<td>12.4-21.1</td>
<td>16.6</td>
</tr>
<tr>
<td>Density at 15°</td>
<td>0.982-0.993</td>
<td>0.950-0.990</td>
<td>0.947</td>
<td>0.9857</td>
</tr>
<tr>
<td>Refractive Index</td>
<td>1.4555</td>
<td>1.456</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>at 71° C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ester Value</td>
<td>39.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Nonsaponifiables (%)</td>
<td>65-67</td>
<td>---</td>
<td>76.7-91.2</td>
<td>---</td>
</tr>
<tr>
<td>Hydrocarbons (%)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>---</td>
<td>65-75&lt;sup&gt;d&lt;/sup&gt;</td>
<td>42.5-59.7</td>
<td>---</td>
</tr>
<tr>
<td>Ash Content (%)</td>
<td>0.05</td>
<td>---</td>
<td>---</td>
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</tr>
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</table>

(Continued)
TABLE III (Continued)

CONSTANTS OF CANDELILLA WAX FROM Pedilanthus pavonis

<table>
<thead>
<tr>
<th>Item</th>
<th>References</th>
<th>Reference 53</th>
<th>Reference 68</th>
<th>Reference 88</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (%)</td>
<td>0.737</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Dielectric Constant</td>
<td>2.50-2.63</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Effective Conductivity</td>
<td>19</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Volume Resistivity</td>
<td>120</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

The ester of sitosterol (C$_{29}$H$_{49}$OH) and dihydroxymyricinoleic acid (C$_{30}$H$_{62}$O$_4$) constitutes about 20 per cent of the ester portion of the wax. Also present are esters of the normal acids and alcohols--C$_{28}$, C$_{30}$, C$_{32}$, and C$_{34}$. Some free resin acids are present as well as amounts of the above acids. (7, 19, 24, 76, 79, 88)

These are data on refined wax.

The hydrocarbons of candelilla wax have been examined by several investigators who report the main hydrocarbon to be a normal C$_{31}$ paraffin. Also present are C$_{29}$ and C$_{33}$ normal paraffins. (1, 7, 19, 24, 26, 35, 53, 57, 70, 76, 80, 88)

This value includes alcohols.
**TABLE IV**

**CONSTANTS OF CANDELILLA WAX FROM**

*Pedilanthus aphyllius*

<table>
<thead>
<tr>
<th>Item</th>
<th>Reference 32</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melting Point, °C</td>
<td>64-65</td>
</tr>
<tr>
<td>Iodine Number</td>
<td>20-21</td>
</tr>
<tr>
<td>Acid Value</td>
<td>18-19</td>
</tr>
<tr>
<td>Density at 15°</td>
<td>1.001-1.002</td>
</tr>
<tr>
<td>Hydrocarbons (%)(^a)</td>
<td>33</td>
</tr>
</tbody>
</table>

\(^a\) The hydrocarbons of candelilla wax have been examined by several investigators who report the main hydrocarbon to be a normal C\(_{31}\) paraffin. Also present are C\(_{29}\) and C\(_{33}\) normal paraffins. (1, 7, 19, 24, 26, 35, 53, 57, 70, 76, 80, 88)
TABLE V
CONSTANTS OF CANDELILLA WAX (SPECIES OF SOURCE UNSPECIFIED)

<table>
<thead>
<tr>
<th>Item</th>
<th>Range of Reported Data</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melting Point, °C</td>
<td>64-77.4</td>
<td>7, 9, 11, 26, 35, 42, 49, 52, 57, 62, 65, 69, 76</td>
</tr>
<tr>
<td>Setting Point, °C</td>
<td>63-68</td>
<td>49, 69</td>
</tr>
<tr>
<td>Saponification Numbera</td>
<td>46.7-106</td>
<td>3, 9, 11, 35, 42, 49, 52, 62, 69, 75</td>
</tr>
<tr>
<td>Iodine Number</td>
<td>5.2-35</td>
<td>3, 9, 11, 35, 42, 52, 57, 65, 69, 76</td>
</tr>
<tr>
<td>Acid Value</td>
<td>8.9-21.13</td>
<td>3, 22, 35, 49, 52, 57, 62, 65, 69, 76</td>
</tr>
<tr>
<td>Density at 15° C</td>
<td>0.936-0.996</td>
<td>3, 9, 11, 42, 49, 52, 57, 62, 65, 69, 76</td>
</tr>
<tr>
<td>Refractive Index</td>
<td>1.456 (75°C)</td>
<td>11, 69</td>
</tr>
<tr>
<td></td>
<td>1.4545-1.4626 (85°C)</td>
<td>11, 69</td>
</tr>
<tr>
<td>Acidity</td>
<td>0.03</td>
<td>11, 42</td>
</tr>
<tr>
<td>Ester Value</td>
<td>33.86-34.1</td>
<td>22, 65</td>
</tr>
<tr>
<td>Fatty Acids (%)</td>
<td>29-54.3</td>
<td>62, 69</td>
</tr>
<tr>
<td>Nonsaponifiables (%)</td>
<td>65-91.7</td>
<td>3, 11, 21, 57, 62, 69, 75</td>
</tr>
<tr>
<td>Hydrocarbons (%)b</td>
<td>42.49-59.7</td>
<td>3, 11, 21, 22, 24, 76</td>
</tr>
<tr>
<td>Ash Content (%)</td>
<td>0.7</td>
<td>65</td>
</tr>
<tr>
<td>Moisture (%)</td>
<td>0.52-1.5</td>
<td>57, 65</td>
</tr>
</tbody>
</table>

a The ester of sitosterol (C_{29}H_{49}OH) and dihydroxymyricinoleic acid (C_{30}H_{62}O_{4}) constitutes about 20 per cent of the ester portion of the wax. Also present are esters of the normal acids and alcohols—C_{28}, C_{30}, C_{32}, and C_{34}. Some free resin acids are present as well as amounts of the above acids. (7, 19, 24, 76, 79, 88)

b The hydrocarbons of candelilla wax have been examined by several investigators who report the main hydrocarbons to be a normal C_{31} paraffin. Also present are C_{29} and C_{33} normal paraffins. (1, 7, 19, 24, 26, 35, 53, 57, 70, 76, 80, 88)
TABLE VI
USES OF CANDELILLA WAX

1. Substitute or dilutant for beeswax
2. Substitute or dilutant for carnauba
3. Hardener for soft waxes
4. Ingredient in acid-proofing agents for metal etching
5. Ingredient in adhesives and cements
6. Ingredient in automobile polishes
7. Ingredient in candles
8. Ingredient in carbon paper, lithographic, printing, stamping, and writing inks
9. Ingredient in celluloid composition
10. Ingredient in chewing gum compositions
11. Ingredient in cosmetic preparations
12. Ingredient in crayons
13. Ingredient in electrical insulating compositions
14. Ingredient in emulsion polishes
15. Ingredient in explosives
16. Ingredient in floor polishes
17. Ingredient in furniture polishes
18. Ingredient in insect-proofing materials
19. Ingredient in leather dressings
20. Ingredient in linoleum

(Continued)
TABLE VI (Continued)

USES OF CANDELILLA WAX

21. Ingredient in lubricant bases
22. Ingredient in metal-protecting compositions
23. Ingredient in molding compositions (dentistry, precision castings, etc.)
24. Ingredient in ointments
25. Ingredient in paint removers
26. Ingredient in paper sizing
27. Ingredient in phonograph records
28. Ingredient in rubber compositions
29. Ingredient in sealing waxes
30. Ingredient in shoe polishes
31. Ingredient in varnishes
32. Ingredient in waterproofing agents (fabrics, shipping containers, etc.)
33. Ingredient in plastics (as plasticizer, filler or base)
34. For molding purposes (figurines, anatomical specimens, etc.)

References: 1, 2, 6, 10, 12, 13, 14, 16, 20, 25, 29, 33, 34, 41, 47, 49, 52, 53, 60, 66, 71, 87, 88, 94.
Apparently the major portion of the candelilla wax imported into this country has been used in the manufacture of polishing and coating preparations. Estimates are that up to 4,000,000 - 5,000,000 pounds of the wax are used annually for these materials. (36, 85) In addition, the chewing gum industry has consumed approximately 3,000,000 pounds* annually in recent years. (51)

For use in polishes, candelilla has been found to have several disadvantages. The wax contains a rather high resin content which imparts a tackiness to the products and causes shutdowns in production by fouling the reaction vessels. However, this property has been used advantageously to impart nonslip properties to floor wax preparations. There has been a trend toward greater demand for emulsion-type wax preparations and candelilla wax is not exceptionally satisfactory in these. In liquid preparations the candelilla wax has a tendency to form objectionable gels. In addition, the present high price of candelilla wax has caused it to be replaced in many formulations by oxidized microcrystalline, ozokerite, and I.G. waxes. (18, 20, 30, 36, 60)

The major objection that chewing gum manufacturers have to candelilla wax is the current high prices, although a wax free of the bitterness of the present grades of candelilla would be appreciated. Considerable research, stimulated by the high prices, has been undertaken recently by chewing gum producers to uncover suitable, lower-priced substitutes for candelilla wax. A microcrystalline wax has been mentioned as successful for this purpose. (31, 51, 55, 58)

*It should be noted that this figure is not in agreement with a recent publication by Sayre and Marsel, Chemical Week 71, No. 13, 29 (September 27, 1952). (77) Our information, obtained by direct contact with the industry, substantiates the three-million-pound figure.
5. Markets

Candelilla wax has been a wax of commerce since about 1912 but did not achieve much prominence until the late 1930's. Several factors contributed to the increase in imports of this material, among which were (1) the increased demand for waxes brought on by World War II and (2) the promotional efforts of a Mexican organization. The United States production of candelilla has been a relatively small percentage of the import volume (estimated at about 10 per cent) and has been sporadic, depending on the price and availability of the imported material.

The wax has been used in volume in such diversified applications as polish foundations and chewing gums. It has numerous other uses which range from cosmetics to waterproofing compounds. Statistics of the volume consumed by industry for each of the various uses unfortunately are not available. However, as previously indicated, the volumes consumed annually in polish formulations and chewing gum have been about five million and three million pounds, respectively. Before 1936, the United States Department of Commerce did not list candelilla individually as an import but combined it with several other vegetable waxes. Consequently, little statistical information is available concerning the economics of the material previous to that date. It can be said, after a consideration of the import and price data of Table VII, that since 1936 candelilla has possessed a turbulent price and supply history. If, after graphical presentation (Figures 1 and 2), an attempt is made to analyze these fluctuations, one immediately encounters such obstacles as smuggling and controlled production and sale.
TABLE VII
IMPORTS FOR CONSUMPTION AND PRICES

<table>
<thead>
<tr>
<th>Year</th>
<th>Candelilla</th>
<th></th>
<th></th>
<th>Carnauba No. 1</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Volume (1,000 lbs.)</td>
<td>Unit Price (Cents/lb.)</td>
<td>OPD Price (Cents/lb.)</td>
<td></td>
<td>Unit Price (Cents/lb.)</td>
<td>OPD Price (Cents/lb.)</td>
</tr>
<tr>
<td>1936</td>
<td>1,804</td>
<td>13</td>
<td>--</td>
<td>34</td>
<td>--</td>
<td>36</td>
</tr>
<tr>
<td>1937</td>
<td>2,844</td>
<td>12</td>
<td>--</td>
<td>35</td>
<td>--</td>
<td>32</td>
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<tr>
<td>1938</td>
<td>1,411</td>
<td>12</td>
<td>--</td>
<td>30</td>
<td>--</td>
<td>29</td>
</tr>
<tr>
<td>1939</td>
<td>3,357</td>
<td>13</td>
<td>17</td>
<td>46</td>
<td>72</td>
<td>69</td>
</tr>
<tr>
<td>1940</td>
<td>5,644</td>
<td>14</td>
<td>19</td>
<td>60</td>
<td>83</td>
<td>64</td>
</tr>
<tr>
<td>1941</td>
<td>7,747</td>
<td>16</td>
<td>21</td>
<td>59</td>
<td>72</td>
<td>67</td>
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<tr>
<td>1942</td>
<td>7,846</td>
<td>20</td>
<td>36</td>
<td>69</td>
<td>88</td>
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<td>1943</td>
<td>10,880</td>
<td>28</td>
<td>38</td>
<td>60</td>
<td>83</td>
<td>74</td>
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<tr>
<td>1944</td>
<td>6,711</td>
<td>28</td>
<td>36</td>
<td>64</td>
<td>83</td>
<td>64</td>
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<tr>
<td>1945</td>
<td>9,678</td>
<td>30</td>
<td>36</td>
<td>67</td>
<td>83</td>
<td>74</td>
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<tr>
<td>1946</td>
<td>7,094</td>
<td>56</td>
<td>79</td>
<td>109</td>
<td>188</td>
<td>115</td>
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<tr>
<td>1947</td>
<td>8,424</td>
<td>32</td>
<td>73</td>
<td>115</td>
<td>160</td>
<td>74</td>
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<tr>
<td>1948</td>
<td>2,593</td>
<td>35</td>
<td>62</td>
<td>74</td>
<td>127</td>
<td>71</td>
</tr>
<tr>
<td>1949</td>
<td>7,114</td>
<td>38</td>
<td>55</td>
<td>71</td>
<td>111</td>
<td>78</td>
</tr>
<tr>
<td>1950</td>
<td>5,699</td>
<td>43</td>
<td>47</td>
<td>78</td>
<td>104</td>
<td>91</td>
</tr>
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<td>1951</td>
<td>4,308</td>
<td>64</td>
<td>71</td>
<td>91</td>
<td>132</td>
<td>86</td>
</tr>
<tr>
<td>1952</td>
<td>2,704</td>
<td>70</td>
<td>76</td>
<td>86</td>
<td>124</td>
<td></td>
</tr>
</tbody>
</table>

a Volume figures were compiled from U.S. Department of Commerce Report No. 110, U.S. Imports of Merchandise for Consumption.

b Unit Price is the value of imports in dollars divided by the volume in pounds.

c OPD Price is average yearly price from the Oil, Paint and Drug Reporter.

d Volume figures for 1952 are the total monthly figures for January-July, 1952; OPD price is the average price for January-July, 1952, as reported in Oil, Paint and Drug Reporter.
In 1936, the Union de Crédito de Productores de la Cera de Candelilla was organized in Mexico for the purposes of collective selling, eliminating foreign exporters, and improving the conditions of the extractors. This group of producers controlled about 80 per cent of the production, and the resultant artificial prices stimulated excessive production. The Mexican government then intervened in 1937 with legislation and the Banco Nacional de Comercio Exterior lent its financial support to the program. An export tax of 40 centavos per kilo (about five cents per pound) was placed on candelilla wax, and a subsidy equivalent to the tax was granted to the producing organizations. This arrangement was subsequently modified to conform with the actual market conditions. That is, if the market value of the wax declined, the price would be lowered by decreasing the tax.

(48) Table VIII presents the export duty which was imposed on candelilla by the Mexican government. When these data are compared with those contained in Table VII, it is evident that the duty has been a relatively large part of the total price of the wax.

In recent years the control of production and the sale of candelilla have been in the hands of another Mexican organization, but its functions are practically the same as those of the original control organization. "The arrangement can perhaps be best described as a combination of private commercial monopoly and government subsidy, price fixing, and control. The price of the wax is established for three-month periods by the Secretaría de Hacienda, which bases each new value on the record of sales for the previous period." (48) The control exerted by the United States Government in the past has been limited to a ceiling price control of about 36-38 cents per pound during the war years. The exceptionally high
### TABLE VIII

MODIFICATIONS OF EXPORT DUTIES ON CANDELILLA WAX
(Indcuding those of tariff ruled November 27, 1947)

<table>
<thead>
<tr>
<th>Date</th>
<th>Basic Duty (Dollars/Pound)</th>
<th>Approximate Complement Tax (Dollars/Pound)</th>
</tr>
</thead>
<tbody>
<tr>
<td>October 8, 1937</td>
<td>0.0504</td>
<td>---</td>
</tr>
<tr>
<td>September 21, 1939</td>
<td>0.0504</td>
<td>0.020</td>
</tr>
<tr>
<td>October 21, 1939</td>
<td>0.0504</td>
<td>0.016</td>
</tr>
<tr>
<td>November 21, 1939</td>
<td>0.0504</td>
<td>0.016</td>
</tr>
<tr>
<td>December 21, 1939</td>
<td>0.0504</td>
<td>0.017</td>
</tr>
<tr>
<td>August 21, 1941</td>
<td>0.0504</td>
<td>0.020</td>
</tr>
<tr>
<td>December 21, 1941</td>
<td>0.0504</td>
<td>0.022</td>
</tr>
<tr>
<td>March 21, 1942</td>
<td>0.0504</td>
<td>0.028</td>
</tr>
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<td>0.035</td>
</tr>
<tr>
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</tr>
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<tr>
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<td>November 15, 1945</td>
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<th>Ad Valorem (Per Cent)</th>
<th>Overtax (Per Cent)</th>
<th>Addition* (Per Cent)</th>
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<td>0.209</td>
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<td>0.245</td>
<td>exempt</td>
<td>-</td>
<td>2</td>
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*The addition value is calculated from the sum of the previous values.
market price of 79 cents per pound in 1946 is attributed partly to the removal of this ceiling price. Currently, the ceiling price is regulated by "Ceiling Price Regulation 31 - Imports," Office of Price Stabilization, Washington, D. C.

From July, 1947, to August, 1948, production of candelilla wax was prohibited by the Mexican authorities (6), and recently it has been prohibited again.

"A Mexican Presidential Decree, published in the Diario Oficial under date of December 6, 1952 and effective the day after publication, totally prohibits the exploitation of candelilla from December 1, 1952, until September 30, 1953," reports P. Miner, American Embassy, Mexico City. A severe penalty is provided for violation of the decree.

"This step was taken to halt extensive exploitation of candelilla plantings in the States of Chihuahua, Coahuila, Zacatecas, Nuevo Leon, Durango, and San Luis Potosi where the specie has been endangered to the point of extinction.

"The exportation of candelilla wax shows a decreasing trend in recent years as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>Short Tons</th>
</tr>
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<tbody>
<tr>
<td>1947</td>
<td>5,160</td>
</tr>
<tr>
<td>1948</td>
<td>685</td>
</tr>
<tr>
<td>1949</td>
<td>2,696</td>
</tr>
<tr>
<td>1950</td>
<td>3,597</td>
</tr>
<tr>
<td>1951</td>
<td>2,670</td>
</tr>
</tbody>
</table>

"In 1950 and 1951 these exports were valued at nearly 30 million pesos a year (about $3.5 million).

"The present concessionaires or holders of exploitation permits are requested to turn in their permits to local agricultural authorities,"
and those having stocks of candelilla wax on hand are asked to submit a
written report on quantities and location of stocks within a period of
15 days from December 1, 1952. No movement of candelilla wax will be
permitted from deposits or warehouses without express authorization of
the Mexican Department of Agriculture."

The wax which was imported into the United States during 1948 came
from stocks and amounted only to about 2.6 million pounds. (8) It
would appear that this drastic reduction in imports should result in a
high price on this material, but this was not the case; the import price
for the year 1948 averaged about 35 cents per pound. This condition per-
haps can be explained by the published estimate that during one year 1,700
tons of wax were taken from Mexico to Texas illegally (74). This does
not seem unlikely since smuggling of candelilla has been reported as early
as 1943 when an estimated 300 tons were illegally exported; at this time
the import price of the wax was only 28 cents per pound. (75) The es-
timated 1,700 tons reportedly smuggled out during 1947-48 would increase
the 1948 import volume to about six million pounds and would seem to justi-
fy the 35 cents per pound import price for that year.

Mexican border patrols reportedly reduced the smuggling of the wax
by 90 per cent during 1949; that is, only about 170 tons was estimated as
illegal trade. (74)

Information concerning illegal trade after 1949 has not been avail-
able, but if the volume figures for 1950 and 1951 are used as a criterion,
when compared to the six to eight million pounds reportedly consumed by
industry, it does not appear improbable that the illegal trade has con-
tinued. The control of production and sale has definitely contributed
to the fluctuating supply and price history of candelilla. However, these variations can be smoothed out somewhat in the data on imports for consumption by the use of three-year running averages as shown in Figure 1. Sufficient information is not available to include a consideration of the volume of contraband material.

Figure 1 shows that the average yearly volume of candelilla imported has ranged from about two million pounds to nine million pounds. The average volume increased during the war years and then decreased in the postwar period and appears to be leveling off at approximately five to six million pounds per year. The price trend in general (Figure 2) has shown a gradual increase since 1936 and a rapid increase since 1950.

There seems to be a general historical relation between the price of candelilla and carnauba waxes. The price relationship is presented graphically in Figure 3, and using statistical methods the data can be expressed from 1940 to 1952 as

\[ Y = 52.18e^{0.01398X} \]

where \( Y \) is the price of carnauba in cents per pound, and \( X \) is the price of candelilla in cents per pound.

The relationship between the prices of candelilla and carnauba is attributed to the fact that candelilla finds application in many of the uses for which carnauba is employed. This is with particular reference to those uses where melting point (or hardness) is not the major criterion of acceptance. In addition to the use as a replacement or extender for carnauba, it is employed in certain carnauba formulations as an additive to impart the property of so-called "tack" to the material. If it could be assumed that this price relationship were exact, it should be possible
Figure 1. Imports of Candelilla Wax for Consumption.
Figure 2. Average Yearly Prices of Candelilla Wax.
Figure 3. Carnauba Wax Price vs. Candelilla Wax Price.
to predict future values for the price of candelilla wax from estimated future prices of carnauba. These carnauba price estimates should not be too difficult to obtain since the carnauba supply situation is not affected by so many uncertain conditions as prevail in the candelilla market. However, since this relationship is not exact, any price estimate based on it would be speculative.

The fact that the price relationship between candelilla and carnauba is neither exact nor a simple straight line function may probably be attributed to several reasons, among which are the fluctuations in demand for candelilla for other uses and the fact that price is definitely not the only consideration in many formulations.

The fluctuations in candelilla demand for other uses is exemplified by the situation regarding floor polishes. Whereas candelilla can be used satisfactorily in paste-type materials, it has not found wide acceptance in the liquid wax preparations. It has been reported that one cause for this is its tendency to form gels in the liquid suspensions, thus reducing shelf life and failing to give the desired finishes from emulsion preparations. (82) Reputedly these conditions have caused a relatively large reduction in the volume of candelilla required for use in floor polishes; in recent years the trend toward the use of liquid and so-called self-polishing waxes has apparently reduced the demand for the paste floor waxes to a relatively large extent.

Another factor which has affected the volume demand has been the high resin content of candelilla wax. The excessive tackiness that the wax possesses has been attributed to the resin impurities. (60) This tackiness has been the cause of a paradoxical situation in that it has
been responsible for the inclusion of candelilla in some formulations, and at the same time has imposed a limit on the volume that could be used in the formulations. This is exemplified by the use of the wax in floor polishes where slip resistance is desired but excessive tackiness must be avoided.

Volume demand for candelilla for some other uses, even with its disadvantages, has been almost independent of price. For example, in recent years about three million pounds per year have been used by the chewing gum industry. Until exceptionally high prices were asked for the wax, the demand for this use was affected very little by the price of the wax.

However, for several other uses the price of the wax has been the major influence on the volume used. That is, when the price of the wax has been considered too high, formulators have searched for and found cheaper materials which possessed many of the advantages of candelilla without some of the disadvantages. In some cases, this has resulted in a permanent loss in the market for candelilla even when the price was reduced. This has been particularly true where the new wax originated from a stable source and did not possess the variable price and supply pattern that has been characteristic of candelilla. The present situation is considered favorable for candelilla since it has been reported that the present supply is adequate for the demand at a price of about 76 cents per pound, and that there is a good and steady demand in spite of this high price. However, the price is definitely considered too high by industry, and for some established uses the price has placed processors at a disadvantage. The volume potential at this price has been estimated
at five million pounds, and the market potential for candelilla wax at 60-65 cents per pound (i.e., about one-half the price of carnauba) has been estimated at about six million pounds per year. There are several factors that could affect the volume potential, including (1) the inroads of lower-priced waxes and (2) the variations in the price and properties of candelilla wax. In general, increased price and replacement by lower-priced materials should result in a decrease in volume used, and decreased price and increased quality should result in an increase in volume used.

There are two schools of thought as to the effect that lower-priced replacements will have on the future volume demand for candelilla. One of these holds that the substitute materials (specifically, the I.G. waxes and microcrystalline waxes) have served primarily to keep the prices of the vegetable waxes from "going out of sight." However, it is conceded that inroads on the vegetable waxes have been made, but that the main use of these waxes has been, and will continue to be, in new applications in a growing wax product market. The other opinion is that the inroads that replacement materials have made will be greatly increased if the prices of the vegetable waxes are not drastically reduced. The acceleration of research programs to find substitute materials by various organizations has been advanced as evidence in support of this opinion.

After considering these general opinions and other detailed variables involved, it seems likely that formulators will continue to use candelilla in established wax preparations with a gradual replacement by other materials to some extent. This rate of replacement should be a function of price, i.e., the higher the price of candelilla the faster the replacement. Also, the replacement waxes will be used in new products which will compete with
the established products for the retail market. This could result in a lower volume demand for candelilla.

The situation is somewhat different with respect to the use of candelilla by the chewing gum industry. There is a real question here as to how long this three-million-pound market will hold at the present high prices. One segment of this industry has already reduced its candelilla consumption by about 65 per cent, and another segment has accelerated its search for a suitable replacement for use in its products. It has been estimated by representatives of this industry that a reduction in price to about 35 cents per pound should serve to hold the present market, and a reduction to 25-30 cents per pound might increase the volume potential by about two million pounds. If the present high prices persist, a loss in volume demand of about one million pounds per year is expected.

A decrease in price and an increase in quality would have far-reaching effects on the volume potential for candelilla for several uses, including (1) polishes and coating formulations, (2) lubricants, (3) carbon paper inks, and (4) so-called self-polishing preparations. A reduction in price to about 35-40 cents per pound at the present quality level should increase the volume potential about one million pounds per year. Such a reduction also should permit processing of the wax for uses where, at present, the processing is prohibited by initial cost.

If the excessive tackiness and poor emulsification properties which have been attributed to resinous impurities could be eliminated, an additional market of two million pounds per year at about 65 cents per pound has been estimated. This figure might be increased up to four million pounds by a price reduction to about 35-40 cents per pound and up to five
million pounds at a price of 25-30 cents per pound. At the present level of 75-77 cents, it has been estimated that less than one million pounds per year additional market would be available for an improved material.

These estimates of the volume potential and future position of candelilla wax can be summarized as follows:

1. The present supply is adequate for a steady demand at a market price of approximately 75-77 cents per pound; the volume potential is estimated at five million pounds.

2. The future volume potential at 60-65 cents per pound is estimated at about six million pounds per year. (The expected drop in the chewing gum industry should be offset by a gain for other uses.)

3. A price reduction to 35-40 cents at the present quality level should increase the volume potential to seven million pounds per year. (The chewing gum industry should not decrease their usage, and an additional one million pounds should be utilized for other uses because of the price reduction.)

4. A drop to 25-30 cents per pound at the present quality level might increase the market to nine million pounds per year because of probable increased usage in the chewing gum industry and others.

5. Removal of impurities and improved emulsification performance at the present price of 76 cents should increase the market potential to about six million pounds per year. A 60-65 cents per pound price should provide a volume potential of about
seven million pounds per year, i.e., increased usage in polish formulations and lubricants, etc.

6. Price ranges of 35-40 cents and 25-30 cents per pound with improved quality might provide volume potentials of about 11 million and 12 million pounds per year, respectively.

If an attempt is made to estimate the volume and price potential for the possible domestic production of candelilla wax, consideration must be given to the future Mexican candelilla position. If the present practice of exploitation of candelilla is continued in Mexico, with the volume of available candelilla plant material decreasing, it seems reasonable to assume that on the average only about five to six million pounds per year of candelilla wax will be imported into the United States on a continuing basis. At a market price of about 76 cents per pound the volume potential for the wax has been estimated at about five million pounds per year. Then, if the price were reduced to 60-65 cents per pound, there should be an annual market for an additional volume of wax up to one million pounds, which could come from domestic sources. This is based on the probability that the Mexican candelilla union would sell about five million pounds of wax by reducing the export tax now imposed to make their price competitive with that of any wax produced elsewhere. It is conceivable that the entire export tax (presently about 25 cents per pound) could be removed, thus making the market price of Mexican wax about 50 cents per pound. This reduction should not affect the profit to the Mexican wax producers; of course, any further reduction in market price would decrease their profit. The decrease in profit that these producers would absorb and remain in operation is not definite. However, in 1937 it is known that
the import price was 13 cents per pound for the wax. This indicates that for all practical considerations they will continue to produce the wax regardless of price.

A reduction in the market price of the wax to 35-40 cents per pound should provide a market for domestically produced material of about two million pounds per year. A reduction to 25-30 cents per pound should increase this volume potential to about four million pounds annually. Better, economically feasible, processing methods might be found by experimentation. Improvements in the quality of the wax which would be obtainable with these better processing methods would appreciably affect the volume potential at all of these price levels.

At 60-65 cents per pound, a domestically produced wax with appreciably decreased tackiness and improved emulsification properties should have a market of approximately two million pounds. In the price ranges of 35-40 and 25-30 cents per pound this figure might be as high as six million and seven million pounds per year, respectively. At the present price of 75-77 cents, a market of less than one million pounds should exist for a domestically produced wax. These estimates are summarized in Figure 4.

It must be remembered that these volume and price potentials, estimated for a possible domestic production, are based on the assumptions that the Mexican producers will continue their present mode of operation, and that imports of the wax will be about five million pounds per year over the range of prices considered. However, under competitive market conditions the Mexican candelilla union might abandon the conservation program and allow excessive amounts of the wax to be produced; the
Figure 4. Volume Potentials for Candelilla Wax at Different Price and Quality Levels.
objective would be to force competitors from the market by making competitive operation economically impractical. There are other factors which also would affect the estimated potentials for domestically produced material. One of these is the possibility of cultivation in Mexico. In the past there has been little interest in such a venture; reputedly there is said to be strong opposition to such developments. (48) A successful domestic development of candelilla might change this situation and stimulate a Mexican cultivation program. If this should occur, the domestic development would be at a disadvantage primarily because of the differential between United States and Mexican labor standards.

The volume estimates given previously are based on market prices, i.e., average yearly Oil, Paint, and Drug Reporter quotations. These figures must be altered considerably to arrive at a price for the wax as harvested on the candelilla plant (hereafter referred to as growers' price). The profit of the brokers in this country and freight costs from point of origin to point of entry can be estimated by considering the difference between the market and import prices as given in Table VII. The import price of the Mexican wax is made up of the export duty, profit to the producing organization, upgrading cost, and the price paid to collectors who do the primary extraction. If the average yearly export duty is subtracted from the import price, an estimate can be obtained of the price that has been received for the wax by the Mexican producers. Beyond this point the reported economics of the wax are confusing and contradictory. However, estimates of the price received by the Mexican extractors can be made if the price of illegally imported wax is considered. In November, 1952, this wax was being bought for about 22.5 cents per pound.
on the Texas side of the Rio Grande River. Obviously, the wax would bring less in Mexico. This price would probably be about 20 cents per pound, and if 2.5 cents per pound is allowed for the extraction cost, the value of the wax on the plant is about 17.5 cents per pound. This value coincides with the figure, based on a recovery of 40 pounds of wax per ton of plant material and an average value of seven dollars per ton, which has been estimated by Texas producers. The range of values for the plant material has been quoted at six to eight dollars per ton, depending on quality.

It should be noted that in February of 1946 operators in this country paid about five dollars per ton for plant material. The operators indicated at that time that production would be discontinued when the market price decreased below 30 cents per pound for the wax. Consequently, it seems reasonable to assume that at a market price of 30 cents per pound the growers' price for the wax in this country would be about 12.5 cents per pound. A decrease in market price below 30 cents would result, of course, in a lower growers' price.

When the growers' price range of 12.5 to 17.5 cents is compared with market prices of 30 to 79 cents per pound, it is apparent that a major portion of the price of candelilla wax goes to the wax producers as profit.

If a straight-line relation is used and the 12.5 and 17.5 cents per pound values are employed as control points, the estimated growers' price for each market price range can be obtained from Table IX. The market price ranges shown in Table IX are the same as those presented in Figure 4.

D. Candelilla as a Crop

It would seem that there is a sufficient, relatively stable demand for candelilla wax to support its continued production in Mexico, or in
Phase Report No. 3, Project No. 177-170

TABLE IX

ESTIMATED GROWERS' PRICE* FOR CANDELILLA WAX

<table>
<thead>
<tr>
<th>Market Price Range (Cents per Pound)</th>
<th>Estimated Growers' Price* (Cents per Pound)</th>
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</thead>
<tbody>
<tr>
<td>25-30</td>
<td>11.9</td>
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<tr>
<td>35-40</td>
<td>13.0</td>
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<td>60-65</td>
<td>15.8</td>
</tr>
<tr>
<td>75-77</td>
<td>17.5</td>
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</table>

* Growers' price is the price of the wax on the plant.
the United States, provided that it could be produced to market at a reasonable price. The consideration of an expansion of domestic production has been warranted since a desire has been expressed for a local source of hard vegetable waxes. Also, Mexican production is apparently limited by decreasing amounts of available plant material in that country; this has been brought about by overproduction during the recent war years, an ineffective conservation program, and a lack of interest in the possibility of cultivating candelilla. This lack of interest in cultivation by the concerns in that country has resulted in practically no available knowledge of the techniques required to propagate and manage candelilla plantings.

1. Economic Potential of Wild Plants

In the past, some quantities of candelilla wax were produced in this country from wild plant material harvested in Texas. Individual operators collected the plants and piled them at roadsides to dry. There the plants were picked up in company trucks and taken to the wax company for extracting and refining the wax. Currently, the producers prefer to outfit the collectors with the necessary tanks, sulfuric acids, etc., for extracting the crude wax and to pay them for the crude wax rather than bother with the bulky plants. (36, 59)

Future production of candelilla wax in the United States in all probability would be limited to areas in Texas and possibly some parts of New Mexico and Arizona. Production from wild plants, of course, would have to be entirely from sources in Texas.

The fact that the program of utilizing wild plants in Mexico has not been too successful, from the standpoint of providing an adequate and
perpetuating supply, indicates that the same type operation would not prove to be adequate in this country. Collection in the wild would have the advantage of not requiring the initial cost of collection of seeds or suitable propagation material, preparation of ground, planting, etc.; however, for successful operation considerable attention would have to be given to the development of suitable conservation practices in order to maintain an adequate, continuing supply of plants. The actual return to the collector would be the value of the plant material minus any fees charged by landowners for permission to harvest the plant material.

Because the wild material would come from scattered areas, as it does in Mexico, the wax would have to be extracted in the field by small operators. The impracticality of transporting the plant material large distances rules out the possibility of a large, centrally located extraction plant and, with the exception of using the spent plant material for fuel, would make the utilization of byproducts not feasible. The cost for production of the crude wax by this method would be comparable to that of production in Mexico, except for the higher labor cost in this country. For this reason, it does not seem that the production of wax from wild plants, beyond the present exploitation, would be economically sound.

2. Economic Potential of Cultivated Plants

Cultivation of candelilla should not be too difficult. The same waste areas where it now grows would probably be used and could be converted into plantation areas by removing interfering brush and other plants and concentrating the candelilla systematically. The plants should
require little attention once growth has been established as they thrive in the wild state. Weeding should not present too much of a problem since the climatic conditions in those areas where candelilla grows are not favorable to the growth of most plants, and the areas do not become overgrown naturally. (48)

Cultivation of the wax plants has the obvious advantage of introducing savings through increased productivity per area of growth, increased productivity per worker in harvesting, and the possibility of mechanical harvesting. Also, there is the advantage of using permanent extraction installations with the possibility of improved methods that could yield more and better-quality wax and the possible utilization of the waste as a byproduct.

The major disadvantages are the lack of knowledge of the culture of candelilla, the difficulties of collection of propagation material, and the speculative nature of competing with the Mexican source.

Cultivated candelilla could be extracted either by the present scheme of small operations or by using a large-scale plant located near the center of the growing area. If the plantings of candelilla are made by individuals in relatively scattered areas, as might be the case if farmers were encouraged to employ part of their land for wax production as an added source of income, small extraction units would probably serve best; the farmer himself would supply the required labor. The farm product in this case would be the crude wax. This method of cultivation would result in a decreased possibility of developing better methods of extraction and would probably make the utilization of byproducts unattractive. However, if the areas of small-scale growth were relatively compactly
located, it might be advantageous to operate a large extraction plant, the farm product in this case being the plant material, which could be collected in trucks as has been done previously in Texas. In the case of such individual plantings, it must be remembered that a conservation program of harvesting only strips, sufficiently spaced, (or some other suitable program) must be employed in order to perpetuate a supply. Otherwise, the planting would have to be remade every so often and there would be several years' wait before the plants matured sufficiently for harvesting.

Plantation-type plantings, large enough to sustain large permanent-type extraction plants, are another possibility. Such plantings would have the advantage of easier control of conservation practices, as well as the advantages of using large-scale plants for extraction. Since the labor under such a program would be hired, the cost probably would be somewhat higher than in the case of the small planting where the labor is done by the farmer himself. This and the initial cost for the larger plant installation, etc., could probably be nullified by the potential increased wax yield (provided that more efficient extraction processes could be developed), and the possibility of an improved, stable-quality wax. Furthermore, the dry wax plants would not have to be transported long distances. However, this is pure speculation since there evidently have been no economic data tabulated for operations based on either of these types of plantings.

In attempting to arrive at a dollar return to the wax plant grower, either on large- or small-scale plantings, there are several factors which definitely must be considered. These are (1) yields of plant
material per acre, (2) production and investment costs, (3) per cent recovery of wax from the plants, and (4) sales price. If all of these data were available, it would be possible to calculate the net return per acre to the wax producer. As has been indicated previously, there are no economic data available on production costs and investment costs for candelilla on either the large- or small-scale plantings. Apparently, no such data are available even from the experimental plantings which have been made. This alone precludes the possibility of arriving at a figure for a net return per acre. In view of this, an alternate method of arriving at an indication of crop value, based on gross returns, might be employed. However, these figures would have to be based on a range of yields of plant material per acre since no yield tests have been reported. Since wild growth has been reported as producing up to ten tons per acre (14, 16), it seems reasonable to assume that larger amounts could be obtained under cultivation. In Figure 5, a nomographical presentation of the variables involved in the determination of gross return per acre, the range of yields of plant material has been extended to 20 tons per acre (inside scale on right-hand side of nomograph). It does not seem that an annual yield per acre could exceed this value, considering the three to five years required for the plant to mature.

The range of the per cent of wax that could be obtained has been taken to include the highest possible yield (5 per cent) based on the reported per cent of wax in the plant material (outside scale on right-hand side of nomograph). The range of growers' price has been extended to about twice the price that is presently paid for crude wax in the United States (inside scale on left-hand side of nomograph). The final
Figure 5. Nomograph for Determining Gross Return Per Acre for Candelilla Wax.
scale, the return to the grower per acre, has been limited to $500 since it is felt that this makes the range extend sufficiently high for practical purposes.

The use of the nomograph is illustrated by the calculation shown by the dashed lines. For example, a two per cent recovery of wax from the plants has been assumed (which is about the percentage realized by the present method of extraction), a growers' price per pound of 17.5 cents (based on an estimated present value (23) of six to eight dollars a ton for the wax-bearing weeds), and a yield per acre of five tons of plant material (assuming 20 tons of growth per acre and an annual harvest of one-fourth that amount). Following the key given, connect the point on scale P which corresponds to the value of two per cent with the point on scale G which corresponds to the growers' price, 17.5 cents. Note the intersection of the line between these points (P and G) and the diagonal reference line of the chart. Extend a line through this intersection and the point on scale Y corresponding to the assumed value of plant yield (five tons) to scale R and read the value of the gross return per acre ($35.00) from this scale.

This return per acre would not indicate that the growing of candelilla would be an exceptionally good crop investment. However, since production and investment costs and yields per acre have not been determined, it would be unwise to discount the possibility of cultivating candelilla. Also, there is a possibility of process improvement which could result in better-quality wax and increased recovery. An experimental program should be undertaken to establish data that are now not available before candelilla is abandoned as a crop possibility.
3. Economic Potential of the Fibrous Residue from Wax Refining

Only one possible byproduct of candelilla wax has been considered in the available literature. This product is a raw material for the production of paper pulp, i.e., the extracted plant material. (16, 17, 48) However, for this to be an attractive source of pulp, the wax plants would have to be processed in a centrally located extractor. The method now used, extraction by small-scale operators, would probably result in the spent plant material's being too scattered to warrant collection for this purpose. Also, small-scale operators are inclined, or need, to use this spent material as fuel for the heat required in the extracting process.

A centrally located plant having a production capacity of 4,000,000 pounds of wax would have a residue of some 95,000 tons of fibrous material. This is based on a two per cent recovery of wax and an additional three per cent loss of material in the extraction process. This byproduct could then supply about 317 tons of fiber material per day to a pulp mill operating approximately 300 days per year.

At least one research organization has expressed the desire to examine the candelilla plants as a paper source, particularly with the idea of producing waterproof paper without impregnation by utilizing the plant's natural wax. (48)

E. Future Considerations for Candelilla

Candelilla wax is in demand in this country, at the present quality level, up to about five million pounds per year at the present price of about 75 cents per pound. Apparently this volume can be supplied by Mexican production. This price is considered too high by industry, and the desire for domestic production to assure a relatively stable price
and quality has been expressed. At the present time, this country does not produce in satisfactory quantities a hard vegetable wax. In times of emergency this could place the United States at a definite disadvantage. This factor and a potential annual market of about seven million pounds for a domestically produced candelilla wax with improved quality and decreased price indicate that the possibility of a domestic development of candelilla should be considered.

The estimated gross return per acre of $35.00 (based on the present percentage wax recovery of two per cent, a yield of five tons per acre per year, and a price of 17.5 cents per pound for the wax on the plant) and the fact that candelilla is a perennial plant do not make the development of candelilla look attractive. However, the development of this plant should not be discounted on this estimate alone, since several factors could markedly improve this situation. Also, since production cost and yield figures for cultivated candelilla have not been determined, the actual net return per acre cannot be obtained conclusively. The two principal factors which would affect the gross return per acre are greater yields and improved recovery of the wax. The maximum possible recovery has been given at five per cent wax by weight of plant. Thus, for any specific yield and sales price, the gross return per acre could be increased by 250 per cent, by increasing recovery from two to five per cent. These conditions indicate that some consideration should be given to the possibility of establishing an experimental program on candelilla wax.

If a program were initiated, it should include studies of

1. experimental plantings to determine:
   a. the proper species and the optimum growing conditions for producing plants of commercial value,
b. production costs,
c. yields per acre,
d. proper harvesting methods, and

2. studies of processing, handling, and marketing procedures and methods in an attempt to:
   a. improve quality,
   b. decrease processing costs,
   c. improve percentage recovery.

After such a program had been completed, correlation of the data obtained should permit an accurate analysis of the feasibility of producing candelilla as a crop.

In conclusion, it can be said that the markets are available for candelilla wax at an improved quality level and at a decreased price. The question which must be answered is whether the wax can be produced economically in this country. If, after experimentation, this is shown to be true, candelilla could conceivably provide a means for increasing the productivity of large areas of land which are at present practically nonproductive.

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V. SIMMONDSIA CHINENSIS

A. Introduction

Simmondsia chinensis—this desert shrub of southwestern United States and Mexico, commonly known as jojoba or Simmondsia, is potentially a very valuable plant. Its value as a browse species in the desert regions has long been recognized, but only in fairly recent years has the vast application of the products of this plant been indicated. Most of these uses, which are as yet unexploited, originate from the liquid wax that comprises about fifty per cent of the dark brown seeds.

B. History

The plant is known in botanical literature as *Simmondsia chinensis* (Link) Schneider of the family Buxaceae, as well as *Simmondsia californica* Nuttall (45, 46, 49, 53). The first of these names, being based on the first specific name that was given to the plant, is the correct one botanically although it perpetuates an error of geography. It is also known by various vernacular names including bucknut, bushnut, coffee berry, coffee bush, goat-berry, goat-nut, hohowi (the original Indian name), jojoba, jojobe, jojove, nutbush, pignut, quinine nut, sheepnut, and wild hazelnut (3, 6, 9, 19, 22, 25, 33, 39, 51, 55, 62). The first mention of the shrub in literature was by the Mexican historian Francisco J. Clavijero, who found that Indians of Baja California highly prized the fruit of jojoba for food and the oil as a medicine for cancer and kidney disorders (21). The Indians in Mexico also prize the oil as a hair restorer (23, 62).

Link (41) first described this plant, which he thought had been collected in China, in 1822 as *Buxus chinensis*. He failed to report it
as being dioecious, as have numerous authors since. (30) The name Simmondsia californica was assigned to the plant by Thomas Nuttall who collected specimens near San Diego, California. "Simmondsia" was chosen "In memory of Thomas William Simmonds, an ardent botanist and naturalist," "californica" denoting the type of locality. (49, 62) Subsequently, it has been found growing in areas of northern Mexico, lower California, islands off the coast of California, New Mexico, and in Arizona. (55, 60, 62) In California it inhabits the mountains bordering the Salton Sea basin of the Colorado desert near Indio and the southern portion of San Diego county. In Arizona the plant seems to be localized in the mountains around Tucson, south and east of Phoenix--the Superstition, Graham, Catalina, Rincon, Santa Rita, Cerro Colorado, Baboquivari and Ajo ranges. A smaller sector of growth exists north of Yuma. (21, 68)

C. Characteristics

1. Botanical Description

Simmondsia is a woody evergreen shrub which is commonly two to three feet high in the wild, occasionally as high as six to seven feet. It is usually easily recognized by its thick, leathery, bluish-green, oblong opposite leaves (one to one-and-one-half inches long), and dark brown nutlike fruit. The seed pod (capsule) is about 3/4 inch long and contains one seed. The seed pod resembles an acorn in that it is abruptly pointed, is ovate and is obtusely triangular. The male (staminate) and female (pistillate) flowers are borne on separate plants, the numbers of male and female plants being about equal in nature. The male flowers are small and appear in rounded, stalked clusters. These apetalous flowers have ten to twelve stamens; the sepals are somewhat petallike, being broadly oblong,
and are soft and hairy. The apetalous female flowers are about 1/2 to 3/4 inch across and are solitary and stalked. The five sepals are egg-shaped to lance-shaped and are soft and hairy. (55, 60, 62)

The plant grows well in dry regions where grasses and other edible herbages are not abundant and is capable of withstanding heavy grazing. The fact that it is evergreen and that an analysis of the foliage has shown it to contain a relatively high percentage of carbohydrate material contribute to its value as a browse species (25). It has been suggested for, and attempts have been made to use it for, artificial range revegetation. Apparently little success was experienced since no records of the results of such attempts were available. (26, 52, 62, 68) Thornber (59) indicates that the rate of growth of the bush is too slow to warrant its use for this purpose.

2. Simmondsia Oil

Simmondsia is unique among plants in that its seed contains an oil which is a liquid wax (for convenience hereafter referred to as oil) rather than a fat. (Waxes are esters of long-chain fatty acids with long-chain monohydroxyl alcohols, whereas fats are esters of long-chain fatty acids with glycerine.) The oil content of the seed does not decrease upon storing over a period of several years, and the properties of the oil are not altered. The oil of Simmondsia seed can be obtained by conventional means (i.e., expression and/or solvent extraction) and is a light yellow unsaturated liquid of unusual stability. The oil is obtained in a remarkably pure state and requires little or no refining for use as a transformer oil, a lubricant for high-speed machinery or machinery operating at high temperature, or for further processing to obtain the
various other potential products. (4, 6, 40, 43, 58) The residual meal from expression or extraction of the oil contains 30-35 per cent protein and is quite acceptable as a livestock feed material. Its use in plastics has also been advanced. (9, 26, 40) *Simmondsia* oil does not become rancid; it is not damaged by repeated heating to temperatures of above 285° C or by heating to 370° C for four days. The color is dispelled by heating for a short time at 285° C; the oil does not change in viscosity appreciably at high temperature and requires little refining to obtain maximum purity. (3, 4, 6, 9, 23, 40, 43, 46, 64) Since the material resembles sperm whale oil both in composition and in properties, it should serve well as a replacement for the applications of this oil. (7, 8, 14, 15, 23, 34, 46, 61)

*Simmondsia* oil can be hydrogenated easily to a hard white wax (hereafter referred to as hydrogenated wax, solid wax, or wax) that has a melting point of about 73° -74° C and is second in hardness only to carnauba. (27, 40, 45) It has been suggested that this wax may be made as hard as carnauba, and it should serve well in wax formulations to replace various imported waxes. (10, 27, 45) In addition, the oil of *Simmondsia* is a potential source of both saturated and unsaturated long-chain fatty acids or alcohols. (45, 46, 57, 58) The oil is also suitable for sulfurization to produce lubricating oil and a rubberlike material (factice) suitable for use in printing ink and linoleum (28, 29, 66, 67).

In 1910 a report was made on some pharmaceutical experiments and a preliminary analysis of the seeds of *Simmondsia*, but actually it did not establish the composition of the oil (50). Later Greene and Foster (33), at the University of Arizona, became interested in the oil because
of numerous references to its medicinal and culinary uses. Their work was the first to disclose the fact that the fatty matter of *Simmondsia* seed was a liquid wax, and they suggested that, because of this, it might have some value for lubricating purposes. Further investigation was then undertaken on the analysis of the oil. The results of determinations of the composition made in England by Green, Hilditch, and Stainsby (32) and in this country by McKinney and Jamieson (44) were published about the same time.

Table X summarizes the reported physical and chemical properties of the oil of *Simmondsia* seed.

*Simmondsia* oil is soluble in common organic solvents such as benzene, petroleum ether, chloroform, carbon tetrachloride, and carbon disulfide but is immiscible with alcohol and acetone.

In spite of the unsaturated nature of the oil it is not easily oxidized and does not become rancid even after standing for long periods of time. However, under proper conditions the oil may be made to react with sulfur to yield a stable product containing a relatively large amount of sulfur, which serves well as a lubricant or as an additive to lubricants. An improved high-pressure gear grease containing sulfurized *Simmondsia* oil sustained the highest pressure recordable on the S.A.E. (Society of Automotive Engineers) pressure lubricant testing machine. (16, 29, 66)

*Simmondsia* oil has several advantages over the similar product from the sperm whale:

1. It possesses no fishy odor; *Simmondsia* oil has a mild pleasant odor.
TABLE X  
PHYSICAL AND CHEMICAL PROPERTIES OF SIMMONDSIA-SEED LIQUID WAX

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glycerol</td>
<td>None</td>
</tr>
<tr>
<td>Oleic Acid</td>
<td>0.66 %</td>
</tr>
<tr>
<td>Palmitoleic Acid</td>
<td>0.24 %</td>
</tr>
<tr>
<td>Saturated Acids</td>
<td>1.54 %, 1.64 %</td>
</tr>
<tr>
<td>Eicosenic Acid (C\textsubscript{20})**</td>
<td>30.3 %</td>
</tr>
<tr>
<td>Docosenoic Acid (C\textsubscript{20})**</td>
<td>14.2 %</td>
</tr>
<tr>
<td>Eicosenol (C\textsubscript{22})**</td>
<td>14.6 %</td>
</tr>
<tr>
<td>Docosenol (C\textsubscript{22})**</td>
<td>33.7 %</td>
</tr>
<tr>
<td>Melting Point</td>
<td>11.2° -11.8° C</td>
</tr>
<tr>
<td>Solidifying Point</td>
<td>6.7° C</td>
</tr>
<tr>
<td>Flash Point (C.O.C.)</td>
<td>555° F.</td>
</tr>
<tr>
<td>Fire Point (C.O.C.)</td>
<td>640° F.</td>
</tr>
<tr>
<td>Viscosity S. U. at 100° F., Sec.</td>
<td>127</td>
</tr>
<tr>
<td>Viscosity S. U. at 210° F., Sec.</td>
<td>173</td>
</tr>
<tr>
<td>Viscosity Index (Dean and Davis)</td>
<td>2</td>
</tr>
<tr>
<td>Color Number (A.S.T.M.)</td>
<td>Nil</td>
</tr>
<tr>
<td>Pour Point</td>
<td>10° C</td>
</tr>
<tr>
<td>Carbon Residue</td>
<td>0.01 %</td>
</tr>
<tr>
<td>Refractive Index at 25° C</td>
<td>1.4648, 1.4650</td>
</tr>
<tr>
<td>Density at 25° C</td>
<td>0.8642, 0.8990</td>
</tr>
<tr>
<td>Specific Gravity 25°/25° C</td>
<td>0.8640</td>
</tr>
<tr>
<td>Saponification Number</td>
<td>92.2, 95.0, 165.7</td>
</tr>
<tr>
<td>Acid Number</td>
<td>0.23, 0.32, 0.57</td>
</tr>
<tr>
<td>Iodine Number (Hanus)</td>
<td>81.7, 88.4</td>
</tr>
<tr>
<td>Acetyl Number</td>
<td>6.8</td>
</tr>
<tr>
<td>Reichert Meissal Number</td>
<td>0.70</td>
</tr>
<tr>
<td>Polenske Number</td>
<td>0.31</td>
</tr>
<tr>
<td>Unsaponifiable Matter</td>
<td>37.62 %, 48.3 %</td>
</tr>
<tr>
<td>Iodine Number of Unsaponifies</td>
<td>77.2, 79.3-80.2</td>
</tr>
<tr>
<td>Acetyl Number of Unsaponifies</td>
<td>171.8, 172</td>
</tr>
<tr>
<td>Soluble Acids (as butyric)</td>
<td>2.43 %</td>
</tr>
<tr>
<td>Insoluble Acids</td>
<td>59.43 %</td>
</tr>
<tr>
<td>Iodine Number of Total Fatty Acids</td>
<td>76.1</td>
</tr>
<tr>
<td>Acid Number of Total Fatty Acids</td>
<td>172.0</td>
</tr>
</tbody>
</table>

*References cited: 32, 33, 35, 38, 44, 46, 64.

**The chief acid, eicosenic, is reported to have the double bond between the 11 and 12 carbon atoms; the chief alcohol, docosenol, is unsaturated in the 13, 14 position. The other alcohol, eicosenol, is probably unsaturated in the 11, 12 position. The position of the double bond in the docosenoic acid was not established, but it has been suggested that it is erucic acid (unsaturated in the 13, 14 position).
2. The crude oil contains no stearins and very little besides the liquid wax, so requires little or no treatment to prepare it for most industrial purposes.

3. It is native to North America and is a vegetable product, and as such, supplies would not be subject to the vagaries of nature to the extent that sperm whale oil is.

With reference to the sulfurized product:

4. Simmondsia oil will take up much larger amounts of sulfur than will sperm whale oil or lard oils (about 25 per cent more).

5. Simmondsia oil does not darken to the same extent as other oils on sulfurization.

6. Highly sulfurized Simmondsia remains liquid, whereas sperm oil, when highly sulfurized, requires mineral oil in order to keep it a liquid. (66)

3. Other Products

By altering the conditions of the addition of sulfur to Simmondsia oil, a so-called factice may be obtained. This rubberlike material is suitable for linoleum manufacture and printing ink composition and has been suggested as a valuable material for the paint and varnish industries and the chewing gum industry. (28, 46, 67)

The liquid oil is transformed into a hard white crystalline wax upon the addition of hydrogen, using nickel-copper catalyst and relatively mild temperatures and pressures. This solid wax has been shown to serve well in polishing wax formulations. A furniture wax polish composition of hydrogenated Simmondsia wax proved to be equal to or superior to some of the popular polishes now on the market. The same results were obtained with an automobile wax composed of hydrogenated Simmondsia wax.
Insufficient experimentation has been conducted to establish the potentials of the product from Simmondsia. It should be applicable in the many fields that require hard waxes. Since this wax is of high purity, it has been suggested that it would be advantageous to utilize other waxes as extenders in its compositions. (2, 31, 40, 45, 46, 56, 58)

The desirability of further investigation of this wax, which could be produced in desert or near desert sections of the United States, is apparent in view of the fact that this country is dependent upon foreign sources for all major vegetable waxes of commerce. Furthermore, no known wax source yields, or promises to yield, an amount of wax comparable to the large quantities that could be obtained from Simmondsia.

In addition to these products, Simmondsia offers a source of numerous other materials. Among these are the two long-chain monoethylenic normal alcohols and acids and the corresponding saturated alcohols and acids. These compounds are not readily available at the present time (common fatty acids contain 16-18 carbons and other common waxes do not contain large amounts of C_{20} and C_{22} straight-chain alcohols), and so their uses have not been extensively investigated. However, the uses of the alcohols in cosmetic preparations, in food preparation (as emulsifying agents), as detergents or wetting agents (as sulfonated material), and lubricants have been considered and show promise of great value. The alcohols have also been proposed as possible competitors of cetyl alcohol in petroleum products, as well as in the previously mentioned uses. There are various patents, issued to cover uses of the alcohols derived from Simmondsia oil, that attest to their potential value. (27, 40, 43, 57)

The long-chain acids might have value in the preparation of soaps, although in all probability they would not prove to be as valuable as
the other products. Apparently there is no reference in the literature to conversion of the wax acids of Simmondsia seed to the alcohols, but it should be possible, by adjusting the conditions of hydrogenation, to convert the oil (including the acid components) to the alcohols. In this manner the entire oil could be utilized for the preparation of alcohols if the acid portions were found to be of little value.

A considerable number of other unique chemical products are apparently available through reactions that are possible because of the chemical nature of the wax, alcohols and acids that are available from the seed of Simmondsia. The development of these products will have to await the production of Simmondsia oil in large enough volumes to insure an adequate supply and to make feasible their investigation by industry.

The digestive systems of animals are not constructed to make use of waxy materials, and so the oil of Simmondsia is not suitable as a food. However, it has been suggested for use as a dressing for those people who enjoy rich salads but who wish to avoid calories. It reportedly has a pleasant taste, but if taken in more than small amounts it will have the same effect as mineral oil. (46) This quality makes the oil a suitable carrier for medicinal preparations that must pass through the stomach into the small intestines before assimilation. It has also been found that Simmondsia liquid wax is useful in the stabilization of penicillin products. In fact it has been shown to be the best liquid wax for this purpose. These preparations of penicillin are also suitable for hypodermic injection. (36, 40, 46)

Simmondsia oil has been shown to inhibit the hydrolysis of vitamin A ester (65) and to have an intense inhibitory action on the growth of
tubercle bacilli. "The virulent *Mycobacterium tuberculosis* when put in contact with the oil did not grow in the usual culture medium." (1) In connection with this latter fact, N. T. Mirow has suggested that *Simmondsia* should be valuable in studying the penetration of bactericidal agents through the waxy sheaths of tuberculosis bacilli. The liquid wax stored in *Simmondsia* seed is utilized during germination as fats are in other plant seeds; hence, Mirow feels that the seeds must contain an enzyme capable of hydrolyzing waxes as lipase does plant seed fats. This enzyme may be capable of destroying the wax coating of tuberculosis bacilli. (1, 45, 46)

**D. Cultivation**

It has been suggested that the answer to the commercial exploitation of this plant and its products is awaiting the growing of the bush under cultivation. (47) The possibility of gathering the nuts in the wild should not be altogether discounted since there is an abundance of seeds produced annually that at the present time is allowed to go to waste. Estimates of the amount of wild nuts available each year range from one hundred million to one billion pounds; the nuts are grown on 100,000,000 acres in Mexico, California, and Arizona--3,000,000 acres in Arizona alone (9). The main drawback to utilizing the wild produce is that attempts to interest laborers in gathering the nuts have been unsuccessful. This has been due in part to the lack of a stable market for the nuts, except for a limited amount which is sold in local markets of Mexico. (52) Other factors which have discouraged collection of the nuts are the facts that the wild shrubs are heavily browsed by deer and cattle, rodents and birds feed on the seeds, the plants are scattered,
only half produce, and in years of extreme drought the seeds do not
develop. However, there is at least one individual in Mexico who is
interested in supplying quantities of *Simmondsia* seed obtained from wild
plants.

The feasibility of cultivation of this plant as a crop has been
demonstrated by at least one small (1/4-acre) plot in California. Several
botanical gardens have grown a few plants, some individuals have made
plantings, and some work has been done on methods of propagation. These
plantings have shown that cultivated *Simmondsia* grows better and yields
a greater amount of fruit of larger size than does the wild plant. Also,
the plant itself grows larger and faster (8 to 10 feet in about 10 to 12
years), particularly if irrigated during the early stages of its develop-
ment. (18, 20, 45, 46, 48, 68)

The natural growing conditions of the shrub would indicate that it
prefers well-drained slopes, at elevations from about 1,500 to 5,000 feet.
The plant grows well above 3,500 feet, but frost damages nearly every crop
at this altitude. The previously mentioned 1/4-acre plot was grown at
practically sea level and has evidently been quite satisfactory. Appar-
etently clay soil is preferred, although under irrigation the plant has
done well in sandy areas. *Simmondsia* has been suggested as a crop on
land adjacent to irrigation projects which are either temporarily or
permanently short of the water required for ordinary crop production. (16)

A major drawback to its cultivation is the fact that the plant takes
approximately six years to reach the stage where the production of seed is
large enough to warrant harvesting on a commercial basis. At the end of
six years it has been estimated that the yield of seed would be about three
or four pounds per plant. It must be remembered that this estimate was based upon observation of those few plants grown in botanical gardens. Another problem is that it is impossible to determine the sex of the plant prior to the time of flowering, which is usually after the plant is three or four years old. Studies at the University of Arizona attempting to determine distinguishing features in the seeds and seedlings have detected no discernible difference. (20)

In actual yield tests as much as 14 pounds of seeds have been secured annually from a plant. (23) No mention was made of the age or size of the plants which produced this weight of seeds, and it was not clear whether this test was on wild or cultivated plants.

Since at least one large-scale planting of *Simmondsia* (640 acres planted near Florence, Arizona) was attempted during World War II without success, it is apparent that its cultivation would not be without difficulties. (3, 5, 9, 11, 13, 23) Considerable attention will have to be given to the selection of the land, seed, and method of planting. It has been suggested that the Arizona bottom lands where this planting was made might have been too cold for the seeds used; the seeds were from Mexico. This planting was made using a modified cotton planter dropping three or four seeds every 78 inches, in rows twelve feet apart. The intention was to thin out surplus male plants to leave about one male for every five female plants when the sex could be determined. By this arrangement there would have been 250 female and 50 male plants per acre. A planting of this type and size could conceivably result in a seed yield of half a ton per acre. This estimate is based upon a yield of four pounds per producing plant, which does not seem improbable. Field tests seem to indicate
that a Simmondsia bush yields about two pounds of seed annually, and it has been reported that much higher yields are possible when the plant is cultivated. An increase in yield of 300 per cent has been suggested. (16, 37, 45, 46, 63) Compare this estimate to the acreage yields that have been reported for other oilseeds (54).

<table>
<thead>
<tr>
<th>Per Cent Oil</th>
<th>Pounds of Seed Per Acre</th>
<th>Pounds of Oil Per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cottonseed</td>
<td>15-18</td>
<td>400</td>
</tr>
<tr>
<td>Soybean</td>
<td>18-21</td>
<td>1100</td>
</tr>
<tr>
<td>Flaxseed</td>
<td>29</td>
<td>520</td>
</tr>
<tr>
<td>Safflower</td>
<td>26</td>
<td>1000</td>
</tr>
</tbody>
</table>

These yields are a ten-year average (1938-47) for domestic oilseeds. Since Simmondsia seeds are 50 per cent oil, the plant would appear to have potentialities as a crop even with the six- to eight-year wait for the first harvest.

Plans had been made to irrigate the planting and to grow an annual crop such as cowpeas, soybeans, or guar between the rows of Simmondsia to offset a part of the expense. In this way the land would not have been completely unproductive for the entire six to eight years required for the first harvest of Simmondsia seed.

Other suggested methods of planting include close spacing, six inches or so apart, to result in hedge rows; the seeds would be planted in flat borders or in a slightly depressed ditch so as to keep them moist until they germinated (about ten days or two weeks). Male plants should be thinned as soon as practical to leave the five-to-one ratio of the sexes. By this method 1,000 or so plants could be grown per acre, and a possible ton-per-acre yield of seed could be realized. It has been suggested that
the very young plants might require protection from extremely hot sun (16, 31, 68).

Propagation by cutting is possible although to date no large plants have been grown in this way. By use of this method it would seem that distribution of the sexes could be accomplished at the time of planting. The main advantage, however, of using this way of planting would be that, by proper selection of shrubs for cuttings, increased yields of oil might be realized. Generally the flowering nodes and leaf nodes are alternate, but some plants flower at nearly all nodes. Also there are some female plants that produce more than one flower per node. By making cuttings of these plants which have a preponderance of flowers a greater number of seeds per plant would be produced. In addition, a selection of the plants which produce the largest seeds could be made. (31) Some experimentation has been carried out on transplanting seedlings of *Simmondsia*. This work indicates that they survive readily, providing the roots are pruned. (18) This would seem to indicate that cuttings could be made and grown in nurseries for later transplanting in the fields. It would appear that the more efficient spacing for this method of planting would be rows 12 feet apart, with bushes in these rows planted about six feet apart. Male bushes would be, of course, systematically interspersed throughout the grove. This type planting would result in approximately 500 female plants and 100 male plants per acre, giving a possible yield of a ton of seed per acre per producing year.

Regardless of the method used for initiating the growth of *Simmondsia*, the planting should be irrigated or watered during its early development. After a substantial growth has been established, it requires
irrigation, to insure a good crop, only if extremely dry weather prevails. Supplemental irrigation is beneficial, however. The young planting should be cultivated to keep weed growth down and hasten the growth as much as possible. (3, 9, 31, 41)

Apparently *Simmondsia* is not bothered seriously by diseases or insect pests. However, there is at least one fungus (*Strumella simmondsiae* Bonar) that has been found on the leaves, calyces, and peduncles, but evidently little damage is caused by it in this country. There is a scale insect that inhabits the leaves of *Simmondsia* that also is not detrimental. There is a harmful pest, probably a microlepidopterous insect, that destroys a large part of the wild crop each year by consuming the very young ovules; it would seem that one spraying at the proper time would be adequate to eliminate this source of damage to the yield. (17, 31, 42)

It has been reported that *Simmondsia* bushes respond well to moderate fertilization although they do not actually require exceptionally good soil (46).

The method of harvesting the seeds might present a problem. In the wild the only method that has been used is hand collection from under the shrub, since the seeds fall from the bush when mature. Under cultivation, hedge row, or orchard-type planting this problem would be lessened, of course, since undergrowth could be kept at a minimum. It has been suggested that the produce could be raked from under the bushes and picked up mechanically by means of a suction machine, separating any debris by fanning. It would be advantageous to prune the lower branches of the plant if this method of harvesting were to be used (31). Another possibility might be a device designed to pick the seeds from the bush prior
to the time of falling. Such a machine has been described, although it was fabricated for picking nuts (12). If a machine were perfected to collect the cultivated seeds, it might be possible to adapt it for use with the wild plants, thereby making utilization of wild Simmondsia feasible.

Interest in producing Simmondsia under cultivation has been expressed by several individuals, and the Instituto Mexicano de Investigaciones Tecnologicas has indicated that they intend to broaden their studies of this plant as they believe the wax has great industrial possibilities. This institute feels that trial plantations should be initiated in northwestern Mexico and southwestern United States, in the areas where Simmondsia now grows wild.

E. Economic Potential of Simmondsia

The possible development of Simmondsia as a domestic crop in some areas of this country should be given careful consideration. The results of small-scale plantings of Simmondsia have indicated that the plant grows well under cultivation and produces larger nuts and higher yields than in the wild. It is also noteworthy that the oil obtained from Simmondsia would be several times the yields of oil received per acre from other oil-seed crops. Other tests have shown that the nuts produced can be processed just as other oilseeds are, using conventional methods and machinery. These factors, when considered with the interest expressed by industry in Simmondsia, point out that this plant has potentialities as a new domestic crop. However, there are several factors which will be of importance in determining the success of the development of this plant. Among these are the dollar return per acre to the farmer and the establishment of suitable markets for the products of the plant.
1. Simmondsia as a Crop

Upon attempting to arrive at a value for dollar return per acre to the farmer for growing Simmondsia, one is faced with the problem of insufficient information. Even if yield figures and the volume and price potentials previously presented are assumed accurate, a reliable dollar return cannot be calculated since the literature does not present adequate information for an analysis of production cost. However, some general estimates and suggestions have been made concerning the economics of cultivation. For example, it has been estimated that the investment and maintenance costs should be somewhat less for Simmondsia than for a citrus grove. Also, it has been suggested that possibly the capital investment might be amortized more rapidly by planting annual crops between the rows of Simmondsia. This could be done at least until the plants begin seed production. The cost of harvesting would depend, of course, on the method employed. If hand picking were used, it should be somewhat cheaper than pecan picking since the nuts could be picked from cleared ground with more produce per unit area. Harvesting cost might be appreciably reduced by the possible adaption of a "vacuum cleaner" type of nut picker which has been developed (12).

Using these general estimates as a guide and employing some reasonable assumptions for the cost of land, labor, irrigation, etc., one might arrive at a production cost for Simmondsia. Then using the estimated price and yield figures, some idea of the dollar return per acre could be obtained. However, this method, at best, would provide an inconclusive estimate. It is believed that until such time as accurate production costs become available the best procedure for obtaining preliminary estimates would be to consider only the gross return figures.
On the basis of the data presented in Table XI and an assumed yield of one ton per acre of seed, it is evident that the gross return per acre for the seed for various industrial uses would be: $100 per acre as a sperm oil replacement and $480 per acre as a carnauba replacement or extender. The one-ton-per-acre estimate is based on the assumption of 500 bushes per acre under cultivation with an average productivity of four pounds per bush. This is twice the yield of the wild plant. On the basis of greater yields which have been suggested as possible (i.e., eight pounds per bush), these figures would, of course, be doubled (63). That is, $200 and $900 per acre, respectively. The acreage required to produce the total estimated 90,000 tons of seed, assuming one ton per acre, would be 90,000 acres. For the industrial use of the oil as a sperm oil replacement 26,500 acres would be needed, and to produce the necessary oil for carnauba wax replacement and extender, 10,000 and 3,250 acres, respectively. These figures would, of course, be halved if the yield were assumed as two tons per acre. The variations on these figures indicate the value and need of accurate yield data.

The gross return per acre for seed appears to be of sufficient magnitude to warrant further investigation; this is particularly true of the gross price value of seed which is to be processed as a replacement or extender of carnauba wax. Such an investigation should provide information on yields per acre and production costs, which would permit an estimate of the dollar return to the farmer and in so doing would help to eliminate one of the present obstacles in the successful development of *Simmondsia* as a domestic crop.
TABLE XI.
VOLUME POTENTIALS AND PRICES FOR SIMMONDSIA OIL

<table>
<thead>
<tr>
<th>Use</th>
<th>Volume of oil (1,000 lbs.)</th>
<th>Price of Oil (Cents per lb.)</th>
<th>Volume of Seed (1,000 lbs.)</th>
<th>Price of Seed (Cents per lb.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sperm Oil Replacement</td>
<td>26,500</td>
<td>11</td>
<td>53,000^b</td>
<td>5^c</td>
</tr>
<tr>
<td>Carnauba Wax Replacement</td>
<td>10,000^d</td>
<td>50.3^e</td>
<td>20,000^b</td>
<td>24.8</td>
</tr>
<tr>
<td>Carnauba Wax Extenders</td>
<td>3,250^d</td>
<td>50.3^e</td>
<td>6,500^b</td>
<td>24.8</td>
</tr>
<tr>
<td>Other Uses</td>
<td>--</td>
<td>--</td>
<td>109,000^b</td>
<td>--</td>
</tr>
</tbody>
</table>

^a The price and volume figures in this table are based on the estimates made in the text of the report.
^b This weight is based on 50 per cent available oil in the seed.
^c This figure is based on one cent per pound assumed for oil extraction cost.
^d The change in weight due to hydrogenation has been assumed negligible.
^e This is based on five cents per pound assumed for processing cost including hydrogenation, extraction and handling cost, and 20 per cent profit to the wax manufacturers.
^f This figure was arrived at by calculating the difference between a 45,000-ton estimate of total potential from previous considerations in the report and 18,250 tons, which represents the potential as a sperm oil and carnauba wax replacement.
2. Markets for Simmondsia Products

There seems little doubt that markets for the products could be developed if the material were available in suitable quantity at a reasonable price, since it has been estimated by representatives of industry that 45,000 tons per year of Simmondsia oil could be used in this country. This estimate includes all uses where the oil and derivatives of the oil would be used as replacements for established materials and, also, other new uses which industrial organizations believe would be developed once the oil was made available.

The price received for the oil would depend upon the price its various products could command. Sufficient information for a detailed cost analysis on each of the uses of the oil is not available. However, several estimates have been made which present some basis for judgment. These estimates should be considered preliminary, however, since many of the potential users contacted have been unfamiliar with the material.

One of the uses of the oil is as a direct replacement for sperm whale oil. In the past 20 years the volume of sperm oil brought into this country has ranged from about 2 million pounds in 1932 to about 43.5 million pounds in 1951; these volumes are the totals of imports for consumption and United States and Alaska production. During the war years (1941-45) the supply of sperm oil was cut off almost entirely, since whaling expeditions to obtain the material were not feasible. This factor and the fluctuating price and supply history of sperm oil have led to interest by industry in a domestic source of a replacement. This interest is evidenced in the estimate made by representatives of industrial organizations that Simmondsia oil could replace sperm oil up to

-90-
100 per cent in this country. This, of course, is based on a price for
the oil competitive with that of sperm oil.

If the data of Table XII are considered, it is evident that since
1939 (with the exception of 1944-46) the volume of sperm oil brought into
the United States for use has ranged from about 7 million pounds to about
43 million pounds. If the values of the three-year running averages are
used, this evaluation is found to be about 18 million pounds in 1939 to
about 29 million pounds in 1950; the average annual volume is about 26.5
million pounds. If it is assumed that the volume potential for Simmondsia
oil as a sperm oil replacement is only as much as the average annual volume
of sperm oil and that the seed contains 50 per cent available oil, then the
potential for the seed is 53 million pounds per year. The import price of
sperm oil during the 1939-51 period fluctuated from a low of about 3.1
cents per pound in 1939 to a high of about 17.9 cents per pound in 1947.
The average price in 1951 was about 13.5 cents per pound, and the present
import price is approximately nine cents per pound. An estimated price of
about 11 cents per pound for Simmondsia oil has been given by representa-
tives of industrial organizations. This figure is based on the 1951 price
and on the value considerations of a stable domestic source of an oil of
the sperm type.

The potential for Simmondsia is increased by the possible demand for
the hydrogenated wax. The various uses for this material, including its
probable position as a replacement for carnauba wax, indicate relatively
large volume potentialities. Statistics for waxes are given in Figures 6
and 7. The extent to which the wax can replace the volume of carnauba
and other waxes used is questionable at this time, but preliminary esti-
mates have been made. It has been estimated that, if the hydrogenated
## TABLE XII

SPERM OIL IMPORTS AND PRICES

<table>
<thead>
<tr>
<th>Year</th>
<th>Volume&lt;sup&gt;a&lt;/sup&gt; (1,000 lbs.)</th>
<th>Three-Year Running Averages of Volume (1,000 lbs.)</th>
<th>Import Price&lt;sup&gt;b&lt;/sup&gt; (Cents per lb.)</th>
<th>Market Price&lt;sup&gt;c&lt;/sup&gt; (Cents per lb.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1931</td>
<td>2,845</td>
<td>---</td>
<td>4.5</td>
<td>---</td>
</tr>
<tr>
<td>1932</td>
<td>1,929</td>
<td>3,234</td>
<td>4.4</td>
<td>---</td>
</tr>
<tr>
<td>1933</td>
<td>4,928</td>
<td>3,896</td>
<td>3.1</td>
<td>---</td>
</tr>
<tr>
<td>1934</td>
<td>4,832</td>
<td>4,722</td>
<td>3.1</td>
<td>---</td>
</tr>
<tr>
<td>1935</td>
<td>4,407</td>
<td>7,104</td>
<td>3.2</td>
<td>8.8</td>
</tr>
<tr>
<td>1936</td>
<td>12,073</td>
<td>9,386</td>
<td>3.2</td>
<td>8.5</td>
</tr>
<tr>
<td>1937</td>
<td>11,678</td>
<td>11,481</td>
<td>3.6</td>
<td>8.9</td>
</tr>
<tr>
<td>1938</td>
<td>10,693</td>
<td>14,332</td>
<td>3.9</td>
<td>8.9</td>
</tr>
<tr>
<td>1939</td>
<td>20,627</td>
<td>18,195</td>
<td>3.1</td>
<td>8.3</td>
</tr>
<tr>
<td>1940</td>
<td>23,266</td>
<td>16,941</td>
<td>4.7</td>
<td>9.6</td>
</tr>
<tr>
<td>1941</td>
<td>6,931</td>
<td>23,763</td>
<td>5.1</td>
<td>10.8</td>
</tr>
<tr>
<td>1942</td>
<td>41,094</td>
<td>26,038</td>
<td>5.2</td>
<td>12.2</td>
</tr>
<tr>
<td>1943</td>
<td>30,090</td>
<td>Not considered because of war shortages</td>
<td>7.4</td>
<td>12.8</td>
</tr>
</tbody>
</table>

(Continued)
TABLE XII (Continued)

SPERM OIL IMPORTS AND PRICES

<table>
<thead>
<tr>
<th>Year</th>
<th>Volume a (1,000 lbs.)</th>
<th>Three-Year Running Averages of Volume (1,000 lbs.)</th>
<th>Import Price b (Cents per lb.)</th>
<th>Market Price c (Cents per lb.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1944</td>
<td>135</td>
<td>Not considered because of war shortages</td>
<td>5.9</td>
<td>13.1</td>
</tr>
<tr>
<td>1945</td>
<td>465</td>
<td>Same as above</td>
<td>7.7</td>
<td>13.1</td>
</tr>
<tr>
<td>1946</td>
<td>908</td>
<td>Same as above</td>
<td>15.6</td>
<td>13.1</td>
</tr>
<tr>
<td>1947</td>
<td>14,918</td>
<td>Same as above</td>
<td>17.9</td>
<td>26.9</td>
</tr>
<tr>
<td>1948</td>
<td>39,564</td>
<td></td>
<td>21,180</td>
<td>14.7</td>
</tr>
<tr>
<td>1949</td>
<td>9,059</td>
<td></td>
<td>28,062</td>
<td>15.4</td>
</tr>
<tr>
<td>1950</td>
<td>35,546</td>
<td></td>
<td>29,361</td>
<td>9.2</td>
</tr>
<tr>
<td>1951</td>
<td>43,460</td>
<td></td>
<td>---</td>
<td>13.5</td>
</tr>
</tbody>
</table>

Volume was calculated by combining imports for consumption and U. S. production. Expressed as crude oil: refined may be converted to crude by dividing by 0.86 gallons, to pounds by multiplying by 7.5. Sources: (a) imports from U. S. Government Reports, Foreign Trade Statistics Report No. FT-110. (b) U. S. production from compilations of the Bureau of Agricultural Economics, USDA, and from communications with the U. S. Department of the Interior, Fish and Wild Life Service.

Import price is based on crude oil by dividing value by volume imported.

Market price was obtained from the Oil, Paint and Drug Reporter for sperm oil, natural winter 45° F.
Figure 6. Imports of Candelilla, Carnauba and Ouricuri Waxes for Consumption.
Figure 7. Average Yearly Prices of Candelilla, Carnauba and Ouricuri Waxes Imported for Consumption.
wax will replace carnauba wax, a market of 10 million pounds per year at half the price of carnauba is feasible. Conversely, if the wax will serve only as an extender for carnauba, the potential volume has been estimated at 20 per cent of the yearly carnauba volume at about half the carnauba price. Samples of the hydrogenated wax have not been readily available. In fact, numerous wax manufacturers and formulators were not aware that this potentially valuable wax existed. The interest of the wax industry in this hard wax, however, is apparent since numerous requests for samples have been received. Samples of the material should be made available, and after distribution to industrial organizations for evaluation much better estimates should be available as to the volume potential of the hydrogenated wax.

The estimated price at which the hydrogenated wax would have to sell, one-half the price of carnauba, would make it competitive with candelilla and carnauba. It has also been suggested that this wax might be competitive with ouricuri for some uses. These price and volume considerations indicate a substantial market for the hydrogenated wax of *Simmondsia*. Another factor of interest is that, in general, domestically produced wax would be in a better competitive position than imported waxes, since such a material would not be subject to as great a fluctuation in supply and price.

Figure 8 presents the relationships among the selling price of hydrogenated wax, the profit to the wax manufacturer, and the price that could be received for the oilseed for this use. The price range chosen for the solid wax is based on half the lowest and highest prices of carnauba wax from the January prices from the *Oil, Paint and Drug Reporter*.
Figure 8. Value of *Simmondsia* Seed Relative to the Price of the Wax.
for the past 15 years. The data presented in Figure 8 have been calculated on the basis of a $0.05 per pound processing cost, including hydrogenation of the oil; it seems reasonable to assume that this cost will not vary appreciably. The per cent profit to the wax manufacturer is based on the oil value plus the processing cost. If it is assumed that the wax will sell for $0.65 per pound, which is approximately half the 1952 price of prime carnauba, and that a very adequate profit to the wax manufacturer will be 20 per cent, the value of about $0.24 per pound for the oilseed can be read from Figure 8.

The data in Figure 6 indicate that the volume of carnauba wax used in this country is about 16.25 million pounds per year on the average. On the basis of using the wax as an extender for carnauba wax up to 20 per cent, and 50 per cent available oil in the seed, it follows that 6.5 million pounds of seed would be needed for this use. However, if it is assumed that the wax is a replacement for carnauba, previous volume estimates indicate that about 20 million pounds of seed would be needed.

Other uses of Simmondsia oil which would increase its volume potential are: as a source for C_{20} and C_{22} saturated and unsaturated alcohols and acids, as a starting material for a factice for use in linoleum and printing ink formulations, and as a raw material for making detergents or wetting agents.

Estimates as to the volume of Simmondsia oil that might be required for producing C_{20} and C_{22} alcohols and acids are not available since these materials are not produced in commercial quantities at present. However, an indication of price might be obtained by comparison with that of cetyl alcohol for which these materials have been suggested as supplements.
Cetyl alcohol has sold for a number of years for about $1.50 per pound. The economic feasibility of producing the alcohols from *Simmondsia* oil has not been established. Consequently, investigation as to the utilization of the C\(_{20}\) and C\(_{22}\) materials is needed, as well as an economic evaluation of the processes by which these materials are obtained from the oil. These investigations and evaluations by industrial organizations, of course, are contingent upon having experimental quantities of the oil readily available.

The expanding demand, in recent years, for detergents and wetting agents indicates a need for stable supply sources of the starting raw materials used. At present, a relatively large volume of detergents is processed from imported raw materials. The extent to which *Simmondsia* oil could be used for this purpose would depend, of course, on the economics involved. However, if one considers the volume of detergents and wetting agents which is derived from materials that are similar to the components of *Simmondsia* (about 100 million pounds from sulfonated alcohols and 44 million pounds from sulfonated waxes, fats, and acids) (47), it can be said that this is another field in which there are vast potentialities which are definitely worthy of investigation.

The potential for *Simmondsia* oil for use in producing a factice is probably not a major one, but it would probably follow if the oil were available on the market.

One byproduct of value from *Simmondsia* seed, which should be of particular interest to the livestock producers in the areas where the plant is known to thrive, is the residual meal. The meal would be obtained after the oil had been extracted from the seed. It is comparable in
protein value to linseed meal, and as a livestock feed supplement should find a ready market at about the price of linseed meal. Any estimates of actual volume demand for this material would be speculations, but based on the history of other oilseed developments, it seems likely that the material would be in demand at a price based on the protein content and on freight rates from the processing points for competitive meals.

Table XI is a recapitulation of estimates of the volume potentials and prices for Simmondsia oil.

F. Future Considerations for Simmondsia

The plant Simmondsia chinensis appears to be potentially a very valuable crop for the desert or semidesert regions of the southwestern United States. The seeds of this shrub provide an oil (liquid wax), similar to sperm whale oil in composition and properties, and a residual meal that should be quite acceptable for livestock feed. In addition, the oil is the source of various other products of potential great value including: a hard white wax, two long chain monounsaturated and saturated alcohols, the acids corresponding to each of these alcohols, lubricating agents, a rubberlike material, and medicinal, cosmetic, detergent, and wetting compositions. The available information concerning the cultivation and harvesting of Simmondsia seed is based either on the wild shrubs or on those few small plantings that have been made; it is insufficient to establish definitely the cost of producing the material on a commercial scale. Although some estimates of the potential markets and the price that could be expected for the products of this plant have been made, a more detailed evaluation must await the availability of sufficient quantities of these products to allow them to be more thoroughly examined by the industrial
users of similar materials. Such examinations would also provide more adequate information on process and handling techniques and costs.

It is believed that experimental plantings should be made of such a size that reliable data pertaining to the costs involved in producing the plant on a commercial scale could be obtained. Representatives of industrial organizations have expressed a very strong feeling that the development of this potentially very valuable desert shrub should not be attempted by industry alone but should be a cooperative endeavor by industry and the appropriate government agencies. Such plantings could serve to develop the required knowledge of best methods of planting, of caring for the shrub, and of harvesting methods that might be applied. These plantings also could provide more reliable information on the yields per acre that could be realized and sufficient sample material for distribution to potential users. The collection of wild produce might also be undertaken to provide the samples for evaluation.

There seems little doubt that the products from _Simmondsia_ oil would be used commercially provided that the seeds could be made available at a reasonable price. In order for the oil to compete with crude sperm oil, it has been estimated that the seeds would have to sell for about five cents per pound. In all probability _Simmondsia_ oil would not require the same refining that crude sperm oil does; therefore, the crude _Simmondsia_ might be competitive with refined sperm oil. This would mean that the seeds could sell for seven or eight cents per pound. On the basis of the price of other oilseeds this price might not appear to be exceptionally attractive; however, the possibility of higher yields per acre than for other oilseeds might offset it somewhat. In addition, the fact that at
times in past years supplies of sperm whale oil have been almost entirely
cut off forcibly points out that the development of Simmondsia as a re-
placement for this strategic material should definitely be considered.

To serve as a hard wax source, the estimated price for Simmondsia
seed would be about 25 cents a pound. This price per pound appears to
be attractive as compared to other oilseeds. The desirability of further
investigation of Simmondsia as a hard wax source is apparent in view of
the fact that this country is dependent upon foreign sources for all
major vegetable waxes of commerce, and no known wax source yields, or
promises to yield, an amount of wax comparable to the large quantities
that could be obtained from Simmondsia.

The total potential for Simmondsia oil has been estimated by repre-
sentatives of industry as 45,000 tons per year. This estimate includes
all uses where the oil and derivatives of the oil would be used as re-
placements or supplements for established materials and, also, new uses
which industry feels would be developed if the oil were available.

Using the assumption that each cultivated shrub would yield twice
the amount of seed as does the wild plant, this represents a potential
crop which would markedly increase the productivity of approximately
90,000 acres of submarginal, semidesert land of the Southwest.

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VI. BAMBOOS

A. Introduction

The Bambuseae tribe is a member of the huge family Gramineae, and bamboos are therefore near relatives of corn, wheat, oats, barley, and other grasses. They are distinguished from other members of the family in that they are woody perennials, some of which are giant species, attaining heights of 60 or more feet. The estimated number of species of bamboo range between 500 and 1,000, composing some 60 or more genera.

(6, 102, 148, 243, 285)

It should be noted that bamboo nomenclature has been, from the beginning, very poorly organized: many species have been assigned different names by different investigators, and the same name has been applied to widely differing species. Even the generic classifications have been in doubt, in that some species have been placed in two or more genera by various workers, and entire genera have been established, only to be removed upon further investigation.

One of the chief reasons for the difficulty in the identification of bamboos lies in the usually great length of the flowering cycle of most species. In most cases a very long time elapses between flowerings; as is sometimes true for other plants, the characteristics of the plant in flower are different from those between flowering periods. Species identification on the basis of the flowering characteristics is therefore extremely impractical for bamboos.

The United States Department of Agriculture has for the past several years devoted much effort to the systematization of bamboo identification, directed both toward reconciliation of existing nomenclature and toward
the establishment of identification keys for the plants in their "normal"
or nonflowering state. A large portion of this work has been conducted
by Dr. F. A. McClure of the Foreign Agricultural Service who is now
recognized as the leading authority on bamboo nomenclature.

A large proportion of bamboo species are native to Asia and adjacent
islands. They are mild-climate plants, and few are native to the colder
temperate regions. Only two species are known to occur naturally in the
United States—Arundinaria gigantea, the Giant Southern cane, and A. tecta,
or switch cane. The largest number of species of a single genus comprise
the genus Bambusa and are native to Africa, India, China, and Japan. Other
important genera are Dendrocalamus (Southeastern Asia and East Indies
Islands), Guadua (South America), Phyllostachys (Eastern Asia), and Sasa
(China and Japan). (See 102, 148, 243.)

The uses of bamboo are almost infinite. In the Orient, particularly,
it is said that most human needs other than food can be supplied by bam-
boo, and the young shoots of many species are esteemed, fresh or preserved,
as a vegetable food. The larger species are used for structural purposes,
furnishing shelter, weapons, bridges, water pipes, etc. Still other species
are suitable for cutting into strips of varying sizes to be used for weav-
ing a type of coarse cloth, bags, baskets, and other items. (5, 10, 27,
112, 135, 140)

The uses to which bamboos are put in the United States are not as
varied as in the Orient, probably because other woods are more avail-
able in the Western Hemisphere. Increasing interest in bamboo has been
shown in recent years, however, particularly for such purposes as light-
but-strong construction, concrete reinforcement (88, 89, 107), and paper
making (22, 38, 40, 94).
B. Characteristics of Bamboos

1. Growth

Bamboos may be divided into two classes: caespitose, or clump-forming, and dumetose, or running. The clump-forming types (representative genera: Bambusa, Dendrocalamus, and Guadua) are generally tropical plants; only a few are hardy enough to endure freezing temperatures. Running bamboos, such as Arundinaria, Phyllostachys, etc., are generally found in temperate regions. They differ from the clump-forming types in that the underground stems, or rhizomes, grow horizontally for some distance, developing lateral buds which sprout to form new culms (stalks). In the case of the clump-forming species, the rhizomes turn up immediately or grow only a short distance before turning upward to form new culms. Bamboos of the genus Chusquea bridge the gap between the clump-forming and running bamboos. Some species of Chusquea exhibit running bamboo characteristics, while others form clumps. (150)

Bamboos grow very rapidly, attaining their full height in six to eight weeks. They also differ from other woody plants in that the full diameter is attained when the culm is only a few inches high. Maturity is not reached, however, until the culm is about three years old. Although the outward physical appearance of the culm does not change after the full height is reached, the cell structure alters radically. The cells, originally thin-walled and full of sap, gradually thicken until the culm is mature. (264)

Sigematu (228), using Miura's durometer to conduct hardness tests on three species of Phyllostachys and one of Arundinaria, found that hardness increases very slowly at first when the growth rate is most rapid, more rapidly as the growth rate decreases, and evenly after growth ceases.
Porterfield (195, 196, 197), in the course of his work on the growth rate of bamboos, came to the conclusion that temperature is the main factor in determining the growth of a culm. His studies on Chimonobambusa (Phyllostachys) quadrangularis and P. nigra revealed that the general slant of the growth curve depends on average thermal conditions; even the hourly rate of growth varies with temperature fluctuations. Some typical growth rates are shown in Table XIII.

**TABLE XIII**

GROWTH RATES OF BAMBOOS (195)

<table>
<thead>
<tr>
<th>Species</th>
<th>Growth Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bambusa gigantea</td>
<td>15.2-36.8 cm/day; 7.8 m/month</td>
</tr>
<tr>
<td>B. balcooa</td>
<td>6.3-22.1 cm/day for 23 days</td>
</tr>
<tr>
<td>B. arundinacea</td>
<td>19.1 cm/day (Aug. 19-Sept. 1) (Chatsworth, England)</td>
</tr>
<tr>
<td>B. arundinacea</td>
<td>55.0 cm/day (Sept. 1-Sept. 7) (Chatsworth, England)</td>
</tr>
<tr>
<td>B. arundinacea</td>
<td>30.5 cm/day (Sept. 7-Sept. 30) (Chatsworth, England)</td>
</tr>
<tr>
<td>Phyllostachys bambusoides</td>
<td>91.4 cm/day maximum; 12.2 meters in 5-6 weeks</td>
</tr>
</tbody>
</table>

In the case of Dendrocalamus giganteus, Osmaston (179) found no direct connection between growth rate and temperature or illumination, although growth during the night was found to be nearly double that in the day. The maximum growth rate was found to occur during the period of highest relative humidity. On September first a growth rate of 13 inches per day was observed; it remained essentially constant for about nine
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days. The culm reached its full height (71 feet) about November 15, at
the end of about three and one-half months of growth.

The size of bamboos at full height varies through a considerable
range, from about 6 inches for small varieties (Arundinaria pygmaea, etc.)
to 70 feet or more for the giant timber bamboos (Phyllostachys bambusoides,
P. vivax, etc.) (243, 263).

The flowering of bamboos is, in most cases, a very unusual occurrence.
Kawamura (129) found that bamboo-brakes composed of the same species uni-
versally and simultaneously flower during a period of a few years and then
wither down, to be restored gradually by new sprouts from the rhizomes.
The flowering was independent of (1) age and extension of brake, (2) thick-
ness of serial stem, (3) fertility or humidity of soil, (4) exposure to
sun, (5) climate, and (6) differences in locality. Observation and his-
torical records indicate that the interval between the flowering periods
of "Hachiku" (Phyllostachys nigra var. henonis) is an integral multiple
of 60 years.

Seifriz (226) noted that the flowering of Chusquea abeitifolia, as
well as of several Oriental giant bamboos (Dendrocalamus strictus, Bambusa
arundinacea, and others), appears to follow a cycle of 32 years; he also
observed that plants of the same species, regardless of age, seem to flower
simultaneously. This observation is confirmed by others (26, 68, 78, 91,
248).

In the opinion of Takenouchi (243), bamboos do not flower at just a
particular season. Flowering and fruiting are usually the result of a
physiological disturbance due chiefly to the poor growth of the vegetative
cells.
2. Propagation

Certain species, such as Dendrocalamus latiflorus, Schizostachyum acutiflorum, and others, produce seeds which germinate readily (243). However, because of the infrequent blooming of most bamboos, and because a large number of species are sterile when they do bloom, propagation by seed is not the most practical of methods.

Clump-forming bamboos may be propagated by cutting the clump into divisions containing one or two culms each. It is usually found best to cut the culms to a maximum height of two feet when this method is used. Some clump-forming species respond well to propagation by culm cuttings, in which single-node sections having a small leafy branch at the nodes are planted. In another method the entire culm is buried; only the leafy branches extend above the surface of the ground. After sprouting and rooting occur at each node, the soil is removed from the center of each internode and the culm is sawed through at these points. A fourth method, not yet widely known and applicable only to certain species, is that of making a single cutting from each of the basal parts of large branches. This method works especially well with those bamboos where the principal branch at each of the lower nodes of the culm generates roots or root primordia spontaneously on the enlarged basal portion while still in place on the culm. (147, 150, 266)

Propagation of the running bamboos is usually effected by some method of rhizome cutting. As noted before, the rhizomes of the running bamboos extend horizontally underground for some distance with new sprouts rising from the rhizomes at intervals. To increase a limited supply of small plants, these are set in a nursery row and grown for a year. After
the new shoots have appeared in the second spring, the connecting rhizomes can be severed and the original plants transplanted with a ball of earth. The new shoots, left in place for a year, repeat the process. (147, 150, 266)

As previously mentioned, bamboos prefer tropical or warm temperate climates. The most desirable soil for most species is a fertile, friable soil, such as sandy loam. Bamboos do not thrive in soils containing excessive moisture or ground in which the water table is close to the surface. The best growing conditions are obtained when the land has good natural drainage and the plants are not exposed to strong winds. (243)

3. Cultivation Problems

a. Insects. One of the most troublesome insects attacking bamboos, particularly the stored, cut culms, is the bamboo powder-post beetle (*Dinoderus minutus* (F.)--order Coleoptera, family Bostrichidae). The damage caused by this beetle is similar to that caused by many other small beetles which attack the harvested wood of several other plants. The adults enter the culm through the breaks in the outer rind, such as the freshly cut ends of poles, trimmed nodes, etc. After entering, they bore tunnels across the grain of the wood and deposit their eggs in the tubular vessels of the severed fibro-vascular bundles. Their larva can completely devour the infested piece. (192)

The most efficient method thus far determined for controlling this pest is treatment with DDT, which may be applied externally in Diesel oil, kerosene (about 5 per cent) or a water suspension (84, 190, 191, 192, 193). Many other methods have been applied: air drying; water curing; internal applications of both copper sulfate and starch-depleting
agents; resin impregnation (192); external applications of dinitro-o-
cyclohexylphenol (190, 192); impregnation with various other chemicals
such as inorganic salt solutions, creosote (104), Wolman salts, borax
(280), and Rangoon oil (237); and heat sterilization in a kiln (100).

Other insects attacking bamboos include locusts (55, 282), termites
(169, 181), aphids (242), and others (62, 243, 275, 276).

b. Scales and Fungus. Bamboos are subject to attack by many
kinds of pests and parasites. The bamboo scales Asterolecanium miliaris
Bdv. and A. bambusae Bdv. and the fungus Loculistroma bambusae are of
particular importance. The chief remedy for the fungus diseases is the
removal and burning of infected culms. Coccinellid beetles observed to
be predatory on scales have been successfully established in some cases.
(32, 51, 61, 64, 66, 67, 96, 103, 116, 137, 153, 164, 184, 185, 227, 247,
253, 254)

c. Other Problems. Because bamboos grow so very rapidly, both
above and beneath the soil, very few plants can interfere with their growth
to any appreciable extent. Some fast-growing vines, however, tend to and
occasionally do smother young bamboo plantings. These vines usually can
be controlled by applying 2,4-D solution. (37)

In studying the growth characteristics of bamboo, investigators have
considered the possible deleterious effects of bamboo-growing on crops
planted later on the same ground. Ferrer Delgado (98), investigating the
effects of bamboo on succeeding crops of bananas, sweet potatoes, tropical
kudzu, and molasses grass, found that no harmful effects resulted and that
yields of the four crops studied were equal to, or higher than, the normal
range for those crops.
4. Harvesting Methods

According to Takenouchi (243) the proper age for cutting bamboo culms varies among species from about two to six years. In general, the larger species require a longer time to reach the harvesting age, which is largely determined by the extent of growth of the rhizomes. The rhizomes of a given plant reach maximum development at two to six years of age, depending on the species (e.g., two years for *Phyllostachys nigra* and six years for *P. edulis*). After reaching maturity they gradually begin to decay, affecting the quality and economic value of the culm. (243)

a. Selective Cutting. The harvesting method reported to be most satisfactory in countries where labor is relatively cheap is the selective cutting of the culms. The culms are marked with the year of emergence as soon as the sheaths are shed (about a month after emergence), and in the harvesting season the culms of proper age are selected and felled with a saw or ax, bundled and carried from the grove. This may be done either annually or biennially. (11, 57, 166, 243)

b. Strip Cutting, or Partial Harvesting. In this method, a portion of the grove is completely cut at fixed intervals, which may be anywhere from one to five years. Since machine harvesting methods may be applied, it requires considerably less labor than selective cutting. Quicker regrowth occurs when the cut sections are interspersed with uncut sections in such a way that the rhizomes of the uncut plants may have ready access to the cut section. (148, 152, 155, 243)

c. Clear Cutting, or Total Harvesting. This method is generally considered quite inefficient in view of the long period of time (10-15 years)
required for a grove to recover after clear cutting. The labor required, however, is the cheapest of the methods discussed. It is considered an extreme measure, to be used to supply a sudden surge in demand. (155, 166, 217, 243)

d. Acreage Yields. Only meager data are available on the number of culms of a particular species which may be expected from a given land area. In February, 1932, McIlhenny (155) obtained the following yields from three plantings at Avery Island, Louisiana:

(1) one acre of 14-year-old Phyllostachys bambusoides, 22,491 canes or 146 tons, gross weight;

(2) one acre of 14-year-old Phyllostachys edulis, 15,876 canes--143 tons; and

(3) a mixed cutting from 2.44 acres of 14-year-old Bambusa multiplex (argentea) and B. multiplex, Variety Alphonse Karr, 11,941 canes--349 tons.

All three cuttings were clean cuts--every stalk was taken from the specified areas.

In July, 1944, the above-mentioned 2.44 acres of mixed bamboo were cut again. Two-thirds of the cane field was taken, yielding 24,600 canes with an average weight of six pounds per cane, or 73.8 tons. One-third was left to encourage further growth, since complete cutting discourages rapid growth. Also in February, 1944, a cutting was made of half the canes from half an acre of the largest species of Phyllostachys. Many of these canes were four to six inches in diameter at the base. Twelve hundred canes were cut, some having a length of 62 feet and a weight of 76 pounds, totaling 39.6 tons.
The above figures represent a rather extreme case, in view of the 14- and 12-year intervals between cuttings. The number of new culms each year is roughly proportional to the number of culms already standing. A more recent study of bamboo yields at Avery Island (232) for plantings five and six years old is summarized in Table XIV.

### TABLE XIV

**BAMBOO YIELDS AT AVERY ISLAND, LOUISIANA**

<table>
<thead>
<tr>
<th>Species</th>
<th>Height of Test Canes</th>
<th>Number of Canes per Acre</th>
<th>Green Weight of Canes per Acre</th>
<th>Dry Weight of Canes per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pseudosasa japonica</td>
<td>17</td>
<td>37,144</td>
<td>55</td>
<td>37</td>
</tr>
<tr>
<td><em>(Arundinaria metake)</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arundinaria gigantea</td>
<td>11</td>
<td>61,299</td>
<td>45</td>
<td>22</td>
</tr>
<tr>
<td><em>(macrosperma)</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bambusa multiplex</td>
<td>29</td>
<td>65,195</td>
<td>244</td>
<td>138</td>
</tr>
<tr>
<td><em>(argentea)</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bambusa multiplex,</td>
<td>23</td>
<td>46,746</td>
<td>105</td>
<td>58</td>
</tr>
<tr>
<td>Variety Alphonse Karr</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Studies of a well-established grove of *Phyllostachys bambusoides* at Savannah, Georgia, indicated that about eight to nine tons per acre per year (somewhat less than the average yearly yield calculated from McIlhenny's figures) may be expected from this species (287). It should also be noted that all of the previously mentioned weight-yield figures (excepting those of Table XIV) are gross weight of green culms, including leaves and branches. (See also 148, 149, 154, 217, 284.)
In India the 1916 yields per acre, tabulated by districts, are reported by Pearson (186) for Bambusa polymorpha, B. arundinacea, Cephalostachyum pergracile, and Melocanna bambusoides. In teak and bamboo forests in the Hlaing Yoma, Okkan, and Thonze areas, in which Bambusa polymorpha and Cephalostachyum pergracile grow, Pearson found the average yield per acre for the former to be 9,255 pounds of dry internodes per acre, while the latter species (in the same area) yielded 8,254 pounds of dry internodes per acre for a total of 17,509 pounds per acre. In the Pyinmana and Toungoo bamboo areas, the total yield of these two species was 39,047 pounds of dry internodes per acre in the same type of forest. In a plot of Melocanna bambusoides thought to be slightly under average, a yield of 16,576 pounds of dry culms per acre was reported. Yields of Bambusa arundinacea varied from 1,975 to 28,968 pounds of dry internodes per acre, depending upon the quality of the forest, with the average tending toward the higher figure.

During the period 1931-35, McClure (149) kept records of the production of new culms from a single culm division of Bambusa breviflora in a 1/10-acre planting on the campus of Lingnan University, Canton, China. His results are presented in Table XV. The decline in the reproduction rate after the first two years was attributed chiefly to increased crowding and the resultant competition for light, moisture, and mineral nutrients.
C. Properties of Bamboos

1. Composition

   a. Cellulosic Constituents. Many investigations have been made into the chemical composition of various species of bamboo. Takenouchi (243) reported a very detailed study made by Komatsu, et al. (132), on the composition of bamboos, including analyses of the shoot and sheaths, the adult culm and culm sheaths, the variation in composition of culm sheaths with age, the variation in composition of nodal and internodal regions with their location on the culm, and changes in the culm's composition from shoot stage to adult stage. These results are presented in Table XXVI-A through Table XXVI-G in Appendix II. Results of other investigators are summarized in Table XVI.
### Table XVI

**Composition of Bamboos**

<table>
<thead>
<tr>
<th>Species</th>
<th>Composition</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Phyllostachys bambusoides</em></td>
<td>Hot-water extract, 14.26%; cold-water extract, 8.43%. The extract contained ash, 38.82%; pentosan, 10.06%; glucose, 12.28%; and nonreducing sugars, 17.71%.</td>
<td>(177)</td>
</tr>
<tr>
<td></td>
<td>The ash consisted mainly of sodium and potassium compounds.</td>
<td>(259)</td>
</tr>
<tr>
<td><em>Phyllostachys bambusoides</em></td>
<td>Ash, 1.19%; benzene alcohol extract, 2.64%</td>
<td>---</td>
</tr>
<tr>
<td><em>&quot;Buloh Plang&quot;--probably Gigantochloa wrayi</em></td>
<td>$\text{H}_2\text{O}$, 11.1%; ash, 3.5%; cellulose (dry basis), 56.25%.</td>
<td>(19)</td>
</tr>
<tr>
<td><em>Ochlandra ridleyi</em></td>
<td>$\text{H}_2\text{O}$, 9.8%; ash, 4.2%; cellulose (dry basis) 55.1%.</td>
<td>(19)</td>
</tr>
<tr>
<td><em>Phyllostachys edulis</em> (Two samples)</td>
<td>Cross &amp; Bevan cellulose, 51.88%, 47.83%; $\alpha$-cellulose, 35.50%, 36.96% (based on oven-dry sample). The $\alpha$-cellulose contained 7.79% and 8.91% pentosans after hydrolysis with 2% $\text{H}_2\text{SO}_4$. The same species yielded 13.52% matter soluble in hot water; of this amount 10.05% was soluble in alcohol. Of the alcohol-soluble portion, 50% was reducing sugar (calculated as dextrose).</td>
<td>(173)</td>
</tr>
<tr>
<td><em>Phyllostachys edulis</em></td>
<td>Moisture, 7.58%; ash, 1.54%; total cellulose, 51.15%; $\alpha$-cellulose in total, 72.65%; lignin, 33.18%; pentosan, 21.92%; nitrogen, 0.19%.</td>
<td>(257)</td>
</tr>
<tr>
<td><em>Phyllostachys (reticulata)</em></td>
<td>Moisture, 7.18%; ash, 1.83%; total cellulose, 56.40%; $\alpha$-cellulose in total, 72.75%; lignin, 32.36%; pentosan, 24.04%; nitrogen, 0.22%.</td>
<td>(257)</td>
</tr>
<tr>
<td><em>Bambusa stenostachya</em></td>
<td>Moisture, 8.12%; ash, 2.45%; total cellulose, 52.20%; $\alpha$-cellulose in total, 76.13%; lignin, 28.77%; pentosan, 19.61%; nitrogen, 0.25%.</td>
<td>(257)</td>
</tr>
<tr>
<td></td>
<td>(Continued)</td>
<td></td>
</tr>
<tr>
<td>Species</td>
<td>Composition</td>
<td>Reference</td>
</tr>
<tr>
<td>---------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-----------</td>
</tr>
<tr>
<td><em>Dendrocalamus latiflorus</em></td>
<td>Moisture, 8.69%; ash, 3.03%; total cellulose, 52.84%; α-cellulose in total, 76.65%; lignin, 26.25%; pentosans, 19.74%; nitrogen, 0.26%.</td>
<td>(257)</td>
</tr>
<tr>
<td><em>Arundinaria alpina</em></td>
<td>Water, 9.5%; water-soluble material, 3.6%; cellulose (in material as received), 47.5% (= 52.5% on dry basis); ash, 1.2%.</td>
<td>(24)</td>
</tr>
<tr>
<td><em>Bambusa multiplex</em></td>
<td>H₂O, 9.7%; ash, 2.0-3.1%; cellulose, 45.0-49.7%, according to stage of maturity.</td>
<td>(245)</td>
</tr>
<tr>
<td><em>Guadua paraguayana</em></td>
<td>Humidity (105° C), 10.29%; ash, 4.73%; pentosans, 17.36%; lignin, 22.19%; ether extract, 0.54%; benzene-alcohol extract, 4.49%; cold-water extract, 2.12%; hot-water extract, 6.32%; one per cent caustic soda extract, 20.01%.</td>
<td>(183)</td>
</tr>
</tbody>
</table>
Schmeil (224) made a thorough study of bamboo fibers and the results he obtained are summarized in the following paragraphs.

The specific weight of the fiber is, with the exception of Bambusa spinosa, larger than 1.0 and is higher in the nodes than in the stem proper. The normal moisture content, averaging nine to ten per cent, is somewhat greater in the nodes than in the internodes and varies considerably depending upon humidity. The fibers are capable of taking up to 17 per cent moisture in a saturated atmosphere. The ash content varies greatly, not only between different species (1.132 to 11.73 per cent) but also in the same species, with the smallest variation found in B. siamensis (3.56 to 11.73 per cent). Relatively larger are the variations in SiO₂ content, 0.116 per cent in B. spinosa and 8.38 per cent in B. siamensis. The total ash in these two cases was reported as 3.15 and 86.3 (sic) per cent.

The ether extract amounts to 0.42 to 1.07 per cent; the alcohol extract is 2.39 to 6.31 per cent. The three to four per cent total extract is less in the case of B. spinosa than in other species, where it varies from four to seven per cent. Bamboo nodes, with the exception of B. siamensis have a higher content of ether- and alcohol-soluble materials than do the internodes. The alcohol extract contains reducing substances, in addition to the resins, fats, and waxes. The acetic acid content, according to Schorger, varies between one and three per cent, with the nodes showing the higher percentage.

The residual stems are rich in starch grains. The protein content, greater in the nodes than in the internodes, was calculated in terms of available nitrogen as 1.94 per cent in B. siamensis and 5.73 per cent (approximately that of straw) in Dendrocalamus strictus. Bamboo's pentosan content also is similar to that of straw. B. spinosa, yielding 16-18 per cent furfural (corresponding to 27-30 per cent pentosans), has the highest amount while other varieties show 20-25 per cent pentosans. Again the nodes contain the larger amounts. The cellulose number, determined according to Cross and Bevan, varies between 56 and 65 per cent and is largest in B. spinosa. The nodes contain less cellulose than the stems. Since the cellulose thus determined contains 22-33 per cent pentosans, the true cellulose content varies between 44 and 46 per cent for the internodes, and 40-44 per cent for the nodes. The lignin content of B. spinosa is 21-23 per cent; in other species it ranges from 24 to 31 per cent. With the exception of B. spinosa, the nodes are richer in lignin than the internodes.
b. Noncellulosic Products. In some species, a siliceous concretion possessed of peculiar optical properties is secreted within the internodes. The substance is called tabashir and was once highly valued in the East for its medicinal properties. (6, 243) More recently it has been found to have wide application as a catalyst because of its microporous structure (69).

The term "bamboo manna" has been used for many years by native physicians in India, and it has been generally accepted as another name for tabashir. Hooper (115) found that this assumption is not valid. He observed an unusual exuded deposit with the appearance of sugar on culms of Dendrocalamus strictus; although none of the natives he questioned recalled seeing the substance before, they believed it to be "bamboo manna."

The material is soluble in water but insoluble in alcohol, ether, and chloroform. Crystals of sugar remain on evaporation. These crystals melt at about 166° C and a little above this temperature assume a brown color and the consistency of barley sugar. Reactions indicate that the chief constituent is a saccharose related to, if not identical to, cane-sugar. The analysis showed water, 2.60 per cent; glucose, 0.75 per cent; ash, 0.96 per cent; and sugar, 95.63 per cent. The material is quite wholesome and can be used in the place of ordinary sugar.

Tsujimoto (252), while conducting experiments on Sasa paniculata, found that the leaves of this species, upon extraction with petroleum ether, yield approximately one per cent of crude wax. When refined with animal charcoal in ethyl acetate, the product was a hard, brittle wax melting at 79°-80° C and possessing, in general, the properties of carnauba wax.
A good grade of activated charcoal has been prepared from *Melocanna bambusoides* and *Dendrocalamus strictus* (168).

The sprouts of various bamboos have also showed traces of HCN (105, 274), as well as nuclease, deaminase, diastase, an enzyme-dissolving fibrin, an enzyme-resembling emulsin, an enzyme capable of hydrolizing salicin (133), and cholin and betain (249). Kozai (134) reported the isolation of asparagine, tyrosin, guanine, hypoxanthine, and xanthene from the water extract of *Phyllostachys mitis* shoots.

Chang (85) reports the isolation of three triterpenoid ketones from the white powder coating the culms of *Bambusa chungii*. These compounds were friedelin (M.P. 255°-260° C), which had previously been found in cork, and two compounds closely resembling friedelin called bambuselin I (M.P. 215°C) and bambuselin II (M.P. 245°C). (See also 56, 60, 108, 127, 131, 172, 174, 236, 240, 241, 243, 250, 268, and 269 concerning constituents.)

2. Physical Properties

One of the most comprehensive series of tests of mechanical properties of bamboos was conducted by Glenn (106) using the species listed below.

- *Arundinaria gigantea*
- *A. simoni var. variegata*
- *A. sp. P.I. No. 76648*
- *A. sp. P.I. No. 77010*
- *Phyllostachys aurea*
- *P. bambusoides P.I. No. 12180*
- *P. bambusoides P.I. No. 40842*
- *P. Flexuosa*
- *P. dulcis (henryi)*
- *P. nigra*
- *P. nigra var. henonsis P.I. No. 24761*
- *P. nigra var. henonsis P.I. No. 75158*
- *P. sulphurea var. viridis*
He conducted flexure, tension, and compression tests, and his results are summarized briefly here.

The modulus of elasticity in flexure varied from slightly below 1,500,000 psi to above 3,000,000 psi, varying not only with the species but among individual members of one species.

The modulus of elasticity in tension and the tensile strength vary in no consistent manner with the age of the culm. Generally, the node is the weaker part of the culm in tension.

The average modulus of elasticity of the several species and varieties of species shows a low value of slightly over 2,000,000 psi and a high value of over 4,500,000 psi with individual species and varieties of species falling well between these limits.

The maximum tensile strength shows the same variation for species and varieties of species when tested with or without a node. The maximum average tensile strength of a species without a node shows a high of just under 50,000 psi and a low value slightly under 26,000 psi. These values are based on a net cross section of bamboo. Those varieties and species which had a high modulus of elasticity had a correspondingly high tensile strength.

The species and varieties which have a pronounced thickening and bulging of the side walls at the node show a corresponding weakness in tension at that point. A study of the fiber bundles at a node of this character would probably show the cause of this weakness.

The average maximum tensile strength of all varieties and species was about 37,500 psi between nodes and about 32,500 psi.
psi at the node. The maximum tensile strength at a node was slightly over 49,500 psi and the minimum value slightly over 18,000 psi. These values are based on the net area alongside the node and do not take into account the increased sectional area of the test specimens due to increased sidewall thickness at the node. In all cases where a splint included the section of a node, the cross-sectional area at the node was greater than elsewhere on the test piece.

Neither the modulus of elasticity nor the maximum tensile strength of the varieties and species tested was changed by treatment with du Pont Methylolurea as shown by the limited number of tests made.

Only one variety of bamboo was tested in compression; this specimen represented culms grown on the campus of Clemson College, South Carolina. The samples tested that had a length in relation to diameter such that cross bending or buckling did not occur showed an average compressive strength of over 8,000 psi and a modulus of elasticity of over 2,160,000 psi.

The value of compressive strength is very much lower than that of tensile strength for the same species.

The modulus of elasticity in compression is only slightly lower than the value in tension.

The results of other tests of mechanical properties of bamboos are included below:

1. *Bambusa tulda*: tensile strength, 52,000 psi.  
2. *Dendrocalamus strictus*, from New Forest, Dehra Dun, India (143):

<table>
<thead>
<tr>
<th>Cutting Date</th>
<th>Age</th>
<th>Modulus of Rupture (psi)</th>
<th>Modulus of Elasticity (1,000 psi)</th>
<th>Maximum Crushing Strength (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>May, 1945</td>
<td>Mature</td>
<td>10,500</td>
<td>1,830</td>
<td>5,150</td>
</tr>
<tr>
<td>May, 1945</td>
<td>Young</td>
<td>79,000 (?)</td>
<td>1,340</td>
<td>3,550</td>
</tr>
<tr>
<td>Dec, 1945</td>
<td>Mature</td>
<td>13,000</td>
<td>2,200</td>
<td>6,000</td>
</tr>
<tr>
<td>Dec, 1945</td>
<td>Young</td>
<td>2,600</td>
<td>1,600</td>
<td>3,400</td>
</tr>
</tbody>
</table>

3. *Bambusa balcooa* and *Dendrocalamus strictus*: modulus of rupture in bending and tensile strength, 14,000 psi; modulus of elasticity, 2.4 x 10^6 psi; maximum crushing strength, 6,500 psi. (162)
4. **Bambusa tuldoides**: longitudinal crushing strength; test culms, length one foot, diameter 5.5 cm., and wall thickness 1.55 cm., supported 15,050 pounds and continued to support 11,650 pounds after the initial rupture. (151) (Note: The higher figure corresponds to a compressive strength of 8,500 psi.)

(See also 35, 47, 70, 89, 95, 107, 110, 246, 262, and 268 for other test results.)

5. **Phyllostachys bambusoides**: density, 35-47 pounds per cubic foot (oven-dry weight and air-dry volume). The density of the wood between nodes was found to be 35 pounds per cubic foot; at the nodes and including wood on each side it was about 47.1 pounds per cubic foot. (54)

**D. Potentialities of Bamboos**

1. **Areas in Which Bamboos May Be Grown**

   The running bamboos, generally more hardy than the clump-forming types, may be successfully grown in practically all portions of the southeastern United States, except in mountainous regions. They are now being grown in Alabama, Florida, Georgia, Louisiana, Mississippi, South Carolina, Texas, and in the eastern parts of North Carolina and Virginia. The clump-forming types are successfully grown in southern Louisiana and Florida. It has been estimated (244) that more than 50,000,000 acres of marginal land in the southern states are suitable for bamboo cultivation.

   The so-called "hardy" bamboos cultivated in the United States are of the genera *Arundinaria* (two species native to this country), *Phyllostachys*, *Pseudosasa*, *Sasa*, *Semiarundinaria*, and *Shibataea*. The term "hardy" is generally accepted as referring to bamboos which are evergreen at temperatures down to about 5° F. Near 0° F. the leaves of all but the hardiest
are killed, and at a few degrees below zero the stems are partially or completely killed. If, however, the rhizomes are reasonably well protected from the cold, new shoots may develop after winters as cold as -20° F. (285)

The United States Department of Agriculture operates the Barbour Lathrop Plant Introduction Garden on the Ogeechee River, near Savannah, Georgia, where experiments are being conducted on about 173 species of bamboo (167). About 37 species are known to be commercially available from nurseries in this country (286).

2. Uses in the United States Compared to Uses in Other Countries

As previously mentioned, the use of bamboos in the United States has been very limited up to the present time. The increased importation of bamboos from the Orient and the increased interest in domestic growing in recent years have resulted in considerable experimentation to determine the practicality of expanding the commercial use of bamboo in several fields.

a. Concrete Reinforcement. Glenn (106, 107) conducted a comprehensive series of tests on bamboo-reinforced concrete in 1943 and 1944, using culms of Arundinaria gigantea with some A. tecta and Phyllostachys bambusoides. One difficulty appeared when this investigation revealed that the modulus of elasticity of the bamboo used was only equal to or slightly less than that of the concrete.* Thus, bamboo as a reinforcement in a concrete member could not prevent its cracking at loads appreciably above...
the ultimate failure figure for a member in which no reinforcement was used. Other general rules stated by Glenn (106) follow:

a. The load capacities at failure increased with increasing percentages of bamboo reinforcement up to an optimum value;

b. This optimum value occurs when the cross-sectional area of the bamboo reinforcement is from three to four per cent of the cross section of the concrete;

c. The ultimate load capacity of a concrete member is increased four or five times above that for the same member without bamboo reinforcement;

d. The safe design load may be increased from two to three times for a member reinforced with bamboo over an unreinforced member.

Complete summaries of tests and design recommendations are given in Appendix II.

Results of a previous investigation (107) indicated that satisfactory reinforcement may be obtained by using a cross section of bamboo ten times that of comparable steel reinforcement. De Simone (233, 234), according to translations of his articles by Holme (113, 114), in the progress of his work on an unstated species of bamboo arrived at substantially the same conclusions as Glenn.

Dahl (88), obtaining material chiefly from tests conducted abroad, reported that it would require an area of bamboo approximately ten times that of steel to provide equal strength; therefore, its extensive use is impractical with beams and slabs of present over-all dimensions. Its weakness to shear forces makes it unsuitable for use in small structures although it might find a limited use in relatively light constructions.
that carry little load and no concentration of loading. However, in these cases it probably would have to be used in conjunction with steel.

Buranasiri (81) conducted a series of tests along the lines of Glenn's investigations, with the same general results. Again the species employed was not stated.

Investigations into the use of bamboo in concrete reinforcement have been made in Germany (89, 162), Italy (113, 114, 233, 234), Japan (230), and in China where bamboo-reinforced concrete has been used in road construction (21) and where concrete piles reinforced with bamboo rods were used in 1919 by the Szechwan-Hankow Railway (83).

Simada (230), conducting a chemical investigation of the bamboo used in concrete, found that the dissolving of the albumin and the saponification of the fatty tissues are due to the calcium hydroxide set free in the chemical combination and hardening of the concrete. At the same time the bond strength is reduced by the expansion and contraction of the bamboo. The natural strength of the bamboo diminishes in 100 days because of its partial solubility in the lime. If, however, measures are taken to prevent the bamboo's being affected by alkali, its strength in the above-mentioned cases increases in 100 days. According to Simada, who has studied the matter both theoretically and experimentally, the problem of preventing the bamboo from being affected by the alkali in concrete is solved. (See also 8, 35, 51, 234)

b. Paper Pulp. Various species of bamboos have been and are being used in the manufacture of paper in many countries, including Argentina (14), China (47), Germany (119), India (14), Indo-China (25), Venezuela (161), and Siam (41). The first to use the material for paper were
the Chinese, who have been making this paper by hand methods for hundreds of years. It is interesting to note that one large use of bamboo in China is in the manufacture of joss paper (a tin-coated paper of bamboo pulp), used for smoke sacrifices at religious and family celebrations. In the Yangtze valley, sales of joss paper amount to $3,927,000 per year (222).

The ancient Chinese method of paper manufacture from bamboo was extremely tedious and inefficient as compared to modern methods; the process developed about the beginning of the Christian era has remained essentially unchanged and is still being used in a small way. The elements of this method are reviewed briefly below (101).

Bamboo stalks of one or two years' growth are split into long sticks from one to one and one-half meters long. These are bundled and soaked in water for about fifteen days; they are then washed in fresh water and laid out to dry in a ditch where they are covered with lime. A few days later they are sprinkled with a little water. After having been washed, wiped, dried and bleached in the sun, the bundles are cut into small sections, put in boiling water and ground in a large wooden vessel to the consistency of very fine paste. An oily and glutinous vegetable extract is added, and the paste is poured into vessels. The workers dip measuring ladles into the paste and draw out the quantity suitable for forming a sheet of paper. Afterward, the sheets are immersed in sizing, a solution of isinglass and alum.

Another process consists of treating unsplit stalks one and one-half to two meters long in a water-filled ditch for about a hundred days. The water is regularly replaced to maintain a constant level. After this prolonged soaking, the mass is beaten with a mallet and heated.
in vats of water to which is added slaked lime. The mixture is boiled for about eight days and nights. This cooking is followed by a hot lye washing. The bamboo fibers are then piled into a large kettle and covered with the ashes of rice straw; the kettle is filled with water and heated to boiling. The second boiling is followed by another lye bath and this succession is continued for about ten days.

After this series of boilings, the fiber mash undergoes a period of fermentation, and the last mechanical grinding takes place in vessels furnished with pounders, for which the power is often supplied by a water mill. The subsequent manufacture of sheets of paper follows the regular form.

Besides the gelatin and alum sizing, the Chinese also apply a sizing made of various starchy materials. It appears that old Chinese paper made for writing needed only a simple sizing, which was ample for the application of Chinese ink made to stroke or brush on paper. Our Western inks and metal pens require very careful sizing to prevent absorption of the ink.

Bamboo pulp manufacture has attained the status of a major industry, however, only in India. The Indian paper industry has been closely associated with the development of bamboo since 1910 (1), and many concessions, such as tax reduction, rent-free land, and others, have been made by the British government to stimulate interest in commercial bamboo farming (44, 50). By 1925 the industry had achieved considerable importance (30), and an article published in 1939 stated that the quality of paper produced by Indian mills utilizing bamboo and sabai grass was equivalent to that of most imported paper of the same class (163). The paper and pulp
section of the Forest Research Institute at Dehra Dun has been responsible for many developments of native fibers for paper making.

About 80,000 tons per year of bamboo pulp are now being utilized in India for the manufacture of paper, including book and writing papers, Kraft paper, and, mixed with mechanical pulp, for newsprint (11, 31). In 1947 a company was formed in Travancore, India, for rayon and paper production, utilizing the enormous bamboo reserves in India, Burma, Malaysia, Kenya, Rhodesia, and British Guiana. Their principal raw material in India was Eetta bamboo, or Ochlandra travancorica (11).

In an article published in 1933, Bhargava (72) briefly summarized the development of the paper industry in India; his summary has been further condensed for presentation here.

An outstanding feature in the history of paper manufacture has been the repeated failure of the staple raw material of the time to provide for the industry's expansion. About the middle of the nineteenth century, cotton and linen rags proved totally inadequate to meet the growing demand for paper. The industry found salvation first in cereal straws and then in esparto grass, until between 1866 and 1870 the paper maker found himself again in straits for supplies of raw material. About this time the development of chemical processes for the conversion of coniferous woods into cellulose came to his aid. Cheap and abundant supplies of pulp gave great impetus to the dissemination of knowledge and growth of civilization, and this in turn led to a continually increasing demand for paper. Today (1933) the world's demand for paper and paper products has reached the colossal figure of over 20 million tons per year, swelled by the requirements of industries developed during recent years, such as artificial silk, photographic films, lacquers, varnishes, explosives, etc. Competent forest authorities have predicted depletion of the accessible coniferous forests in less than 40 years' time, and even scientific measures for the conservation and regeneration of forests cannot bridge the awkward gap expected between the virtual exhaustion of the existing primeval forests about 40 years hence and the time of harvesting the young crops, which will be mature for exploitation in about 60 years.
Investigations carried out during the last 20 years at the Forest Research Institute, Dehra Dun, India, show that bamboos and savannah grasses are the only materials of which abundant supplies are available in India under economical conditions and which can be utilized on a commercial scale as raw material for paper making. It appears further that the majority of savannah grasses can hardly compete with bamboo, either in yield or quality of cellulose obtained. Almost inexhaustible supplies of bamboo are available in tropical and subtropical regions, and, in addition, bamboo has proved to be excellent material for the paper and cellulose industries. As bamboo is the only material that can be used to any considerable extent as a substitute for wood, it is, therefore, only a question of time until bamboo will take its place alongside coniferous wood as a staple raw material for the cellulose industries. (72)

The individual who is perhaps most responsible for developing the Indian bamboo paper industry to its present status is William Raitt, who since 1907 has been closely associated with the development of bamboo as a paper pulp source. Up until about 1912 it was thought necessary to remove the nodes from bamboo culms before digestion (200, 206). This materially decreased the amount of cellulose from a given quantity of raw material and greatly increased the production expense. In 1912 (199, 201, 212, 215), Raitt, conducting investigations on the pulping characteristics of Bambusa tulda, B. arundinacea, B. polymorpha, Cephalostachyum pergracile, and Melocanna bambusoides, found it unnecessary to reject the nodes provided the following treatment was adopted: the culms should not be cut until the shoots of the year are full-grown; a seasoning period of not less than three months should elapse before the culms are used; crushing, extracting starchy matter, and digesting with sulfate liquor should follow. The sulfite and soda processes were found to be uneconomical for use with bamboo, chiefly because of the difficulty of bleaching the resultant pulp. Also in 1912, Raitt and his associates began the development of the "fractional digestion" method of pulping (182, 205, 208,
which, when applied to the sulfate process, decreased the quantity of chemicals necessary, lowered the cooking time and temperature and increased the yield of pulp. Essentially, the process consists of the removal of the soluble substances in the raw material by stages according to their widely differing degrees of solubility. The details of this method will be discussed in a later section. This process is considered a great advance because grasses contain constituents which, if allowed to interact under an "all in" or "overhead" digestion system, produce color reactions which render the pulp economically unbleachable (204).

Raitt has repeatedly advanced claims (17, 202, 209, 210, 213, 216) that bamboo can save the world from the expected serious paper shortage by supplying practically inexhaustible quantities of pulp.

Published investigations of bamboo as a pulp source in the United States to date have been chiefly conducted by the Herty Foundation Laboratory at Savannah, Georgia. Some work has been conducted by various other firms, but their results have not as yet been made public. The Herty Foundation's work has been in progress since the early 1940's, although some investigators in this country became interested in bamboo paper as early as the 1920's (117). Experiments have been conducted on several species, but the most promising results to date have been obtained from the giant timber bamboo (Phyllostachys bambusoides). These preliminary results indicate that both high-grade paper and newsprint can be made from timber bamboo, although it is yet to be determined whether bamboo can compete economically with pine for pulping purposes. It was also found that bamboo pulp would not be judged satisfactory for some products, such as rayon, since the color of the pulp is dark and the water-soluble matter,
pentosan, and ash contents are somewhat high when compared to wood pulp. (12, 40, 94, 136) These tests will be discussed in more detail later in the report.

(1) Species of Bamboo Suitable for Paper Pulp.

(1.1) India. About thirteen species of bamboo have been discussed in the literature with regard to pulp production in India and surrounding countries. Some of these species are referred to by names which are not in accord with present usage; they are listed here, however, by the names used in the articles discussed. Various methods of pulp production have been used with these species, and yields varying from 40 per cent to 60 per cent unbleached pulp have been obtained. All the species mentioned have been found suitable to some degree for paper making.

Bambusa arundinacea (2, 41, 71, 72, 128, 186, 187, 199): large stands in India and Siam,

Bambusa multiplex (nana) (33, 245): found in Mauritius; yield good, but somewhat lower than that of B. tulda,

Bambusa nutans (75): pulp somewhat dark, difficult to bleach,

Bambusa polymorpha (41, 71, 72, 186, 187, 199): one of the most suitable species for location and quantity,

Bambusa tulda (33, 71, 75, 199): plentiful, but pulp somewhat difficult to bleach,

Cephalostachyum pergracile (41, 72, 186, 199): considered one of the most promising pulp sources,

Dendrocalamus hamiltonii (71),

Dendrocalamus longispathus (71, 74): yields as high as 62 per cent unbleached pulp,

Dendrocalamus strictus (2, 49, 71, 72, 75, 128): enormous reserves in India; considered difficult to bleach,

Melocanna bambusoides (71, 72, 186, 187, 199): considered promising for quantity, location, and ease of pulping,
Ochlandra brandisii (72),
Ochlandra nigrocalicata (71), and
Ochlandra travancorica (11, 60, 71): one of the principal Indian pulp sources; has been used in rayon manufacture.

1.2 China and Japan. The Chinese and Japanese literature contains reports on oriental running bamboos as well as tropical varieties from Malaya, etc. The following species are included among those investigated for paper making in these countries:

Bambusa stenostachya (47, 257),
Dendrocalamus latiflorus (47, 257),
Gigantochloa wrayi (19),
Sinocalamus (Leleba) oldhami (47),
Ochlandra ridleyi (19),
Phyllostachys bambusoides (152, 175, 256, 259),
P. edulis (152, 173, 257),
P. conesta (152),
P. lithophila (47),
P. makinoi (47): abundant in Formosa (Taiwan),
P. nidularia (152),
P. nigra var. henonis (152),
P. edulis (pubescens) (125, 175, 176), and
P. bambusoides (reticulata) (257): high pentosan content.

1.3 Africa. The chief African bamboo used for paper making is the African alpine bamboo, Arundinaria alpina, of which large stands are found in Kenya colony. This material is found to be quite satisfactory for pulp (24).
(1.4) South America. Some of the bamboos grown in South America are quite suitable for pulping purposes, although there is practically no commercial-scale pulping in progress. During World War II the factory "Celulosa Argentina," near Rosaria, manufactured pulp from Guadua angustifolia (180). In 1935 a small mill, capable of producing 100 tons of pulp per week, was built six miles from Port of Spain on Trinidad. This mill was erected to convert into pulp the raw material from 1,000 acres of Bambusa vulgaris owned by Thomas Nelson and Sons, Ltd., of Edinburgh, Scotland. An acid pulping process was employed. (198) The project operated intermittently, and economic and technical difficulties caused it to be abandoned in the 1940's (152). About 1939, preliminary investigations were begun on bamboo in Cuba, where it was concluded that bamboo growth and pulping were impractical from an economic standpoint. (188)

Bambusa vulgaris is not native to the South American area, but was introduced there from India about 150 years ago (277). Other species suitable for paper making found in South America include Guadua aculeata, Melocanna baccifera (152), Guadua paraguayana (183), Guadua trinii (180), Chusquea marosissima (180), and a Brazilian bamboo referred to as Tabocca brava (28). Another South American species, Guadua angustifolia (18, 152), has been found to compare favorably as a pulp source with the Indian Bambusa tulda and the African Arundinaria alpina.

(1.5) Philippines. One of the Philippine bamboos investigated for paper-making suitability is Schizostachyum lumampac, which grows abundantly in the islands (57). Other investigations on Philippine bamboos report successful pulping results, but identify the
species only as the "dwarf" variety and the "structural" variety (23, 42, 218).

(1.6) United States. Published investigations on bamboo pulping in this country, with few exceptions, have been confined to the use of *Phyllostachys bambusoides* (53, 54, 136, 144). Lau (139), conducting experiments on *Phyllostachys bambusoides* and *Bambusa tulda*, both grown in the United States, reported that the latter gave the better pulp yields although it is more resistant to pulping and requires longer digestion time. In his experiments, the pulping process consisted of cooking the material under pressure with an aqueous solution of sodium xylenesulfonate. Comparative data on the performance of two species under the more common pulping conditions are therefore unavailable.

(2) Sizes of Fibers Obtained from Various Species. With the increasing interest in bamboo as a pulp source, a considerable number of measurements of bamboo fibers have been made. Table XVII shows some of the data obtained from the literature.

Table XVIII consists of the data of Uno (267, 270) and Nikoku, as presented by Takenouchi (243).

An important factor in paper making is the length-to-width ratio of the fiber used. A long, narrow fiber (high length/width ratio) is best suited to the manufacture of paper.

Some of the length/width ratios for fibers of various bamboo species which are presented in Table XIX are taken from Takenouchi (243); the other figures are calculated from Table XVIII.
<table>
<thead>
<tr>
<th>Species</th>
<th>Fiber Length (mm.)</th>
<th>Width (mm.)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arundinaria alpina</td>
<td>1.6 - 2.7</td>
<td>2.3</td>
<td>(7, 24)</td>
</tr>
<tr>
<td>Arundinaria alpina</td>
<td>16* - 27*</td>
<td>0.023</td>
<td>(118)</td>
</tr>
<tr>
<td>Bambusa arundinacea</td>
<td>1 - 3</td>
<td>0.010-0.015</td>
<td>(118)</td>
</tr>
<tr>
<td>Bambusa blumeana</td>
<td>2.5 - 3.0</td>
<td>---</td>
<td>(118)</td>
</tr>
<tr>
<td>Bambusa lumampao</td>
<td>2.5 - 3.0</td>
<td>---</td>
<td>(118)</td>
</tr>
<tr>
<td>Bambusa multiplex (nana)</td>
<td>--- - 1.6 - 1.9</td>
<td>---</td>
<td>(43)</td>
</tr>
<tr>
<td>Bambusa multiplex (nana)</td>
<td>0.5 - 3.7</td>
<td>1.9</td>
<td>(245)</td>
</tr>
<tr>
<td>Bambusa tulda</td>
<td>---</td>
<td>2.4</td>
<td>(43)</td>
</tr>
<tr>
<td>Bambusa tulda</td>
<td>1.8 - 3.5</td>
<td>---</td>
<td>(118)</td>
</tr>
<tr>
<td>Cephalostachyum pergracile</td>
<td>0.45 - 4.5</td>
<td>0.009-0.030</td>
<td>(118)</td>
</tr>
<tr>
<td>Dendrocalamus latiflorus (1-yr. crop)</td>
<td>---</td>
<td>3.782</td>
<td>0.0214</td>
</tr>
<tr>
<td>Dendrocalamus latiflorus (mature)</td>
<td>---</td>
<td>3.530</td>
<td>0.0210</td>
</tr>
<tr>
<td>Gigantochloa apus (Bambusa apus?)</td>
<td>1.6 - 4.6</td>
<td>---</td>
<td>0.008-0.024</td>
</tr>
<tr>
<td>Gigantochloa maxima</td>
<td>2 - 4</td>
<td>0.014-0.036</td>
<td>(118)</td>
</tr>
<tr>
<td>Gigantochloa wrayi (probably)</td>
<td>1.4 - 3.6</td>
<td>2.4</td>
<td>(19)</td>
</tr>
</tbody>
</table>

(Continued)
TABLE XVII (Continued)
SIZES OF BAMBOO FIBERS

<table>
<thead>
<tr>
<th>Species</th>
<th>Fiber Length (mm.)</th>
<th>Width (mm.)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guadua angustifolia</td>
<td>1 - 4</td>
<td>0.005-0.56*</td>
<td>(118)</td>
</tr>
<tr>
<td>Ochlandra ridleyi</td>
<td>1.0 - 4.2</td>
<td>2.3</td>
<td>(19)</td>
</tr>
<tr>
<td>Phyllostachys bambusoides</td>
<td>0.3204 - 3.4218</td>
<td>1.4774</td>
<td>(53, 136)</td>
</tr>
<tr>
<td>Phyllostachys makinoi</td>
<td></td>
<td>2.54</td>
<td>(47)</td>
</tr>
<tr>
<td>(1-year crop)</td>
<td></td>
<td>2.65</td>
<td>(47)</td>
</tr>
<tr>
<td>Phyllostachys makinoi</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(mature)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schizostachyum lumampao</td>
<td></td>
<td>2.5-3.0</td>
<td>(57)</td>
</tr>
</tbody>
</table>

*A decimal-point error has evidently occurred here. The values probably should be 1.6, 2.7, and 0.005-0.056 mm.*
### TABLE XVIII

**SIZES OF BAMBOO FIBERS**

<table>
<thead>
<tr>
<th>Species</th>
<th>Fiber Length (mm.)</th>
<th></th>
<th>Width (mm.)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max.</td>
<td>Min.</td>
<td>Average</td>
<td>Max.</td>
</tr>
<tr>
<td><em>Phyllostachys bambusoides</em></td>
<td>1.802</td>
<td>1.348</td>
<td>1.575</td>
<td>0.0138</td>
</tr>
<tr>
<td><em>P. nigra var. henonis</em></td>
<td>1.947</td>
<td>1.508</td>
<td>1.728</td>
<td>0.0158</td>
</tr>
<tr>
<td><em>Phyllostachys edulis</em></td>
<td>1.788</td>
<td>1.331</td>
<td>1.560</td>
<td>0.0138</td>
</tr>
<tr>
<td><em>Phyllostachys makinoi</em></td>
<td>4.000</td>
<td>0.700</td>
<td>2.500</td>
<td>0.0290</td>
</tr>
<tr>
<td><em>Phyllostachys lithophila</em></td>
<td>1.795</td>
<td>1.080</td>
<td>1.438</td>
<td>0.0163</td>
</tr>
<tr>
<td><em>Dendrocalamus latiflorus</em></td>
<td>1.735</td>
<td>1.100</td>
<td>1.418</td>
<td>0.0134</td>
</tr>
<tr>
<td><em>Bambusa stenostachya</em></td>
<td>1.814</td>
<td>1.148</td>
<td>1.481</td>
<td>0.0155</td>
</tr>
<tr>
<td><em>Sinocalamus (Bambusa) oldhami</em></td>
<td>1.909</td>
<td>1.041</td>
<td>1.475</td>
<td>0.0138</td>
</tr>
</tbody>
</table>
Table XIX
LENGTH/WIDTH RATIOS OF BAMBOO FIBERS

<table>
<thead>
<tr>
<th>Species</th>
<th>Ratio</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arundinaria alpina</td>
<td>100.0a</td>
<td>(24, 118)</td>
</tr>
<tr>
<td>Bambusa arundinacea</td>
<td>160.0b</td>
<td>(118)</td>
</tr>
<tr>
<td>Sinocalamus (Bambusa) oldhami</td>
<td>128.3</td>
<td>(243)</td>
</tr>
<tr>
<td>Bambusa stenostachya</td>
<td>133.6c</td>
<td>(243)</td>
</tr>
<tr>
<td>Cephalostachyrium ber gracile</td>
<td>124.0b</td>
<td>(118)</td>
</tr>
<tr>
<td>Dendrocalamus latiflorus</td>
<td>123.3a</td>
<td>(243)</td>
</tr>
<tr>
<td>D. latiflorus (1-year crop)</td>
<td>176.7a</td>
<td>(47)</td>
</tr>
<tr>
<td>D. latiflorus (mature)</td>
<td>168.1</td>
<td>(47)</td>
</tr>
<tr>
<td>Gigantochloa apus (Bambusa apus?)</td>
<td>193.8b</td>
<td>(118)</td>
</tr>
<tr>
<td>Gigantochloa maxima</td>
<td>120.0b</td>
<td>(118)</td>
</tr>
<tr>
<td>Guadua angustifolia</td>
<td>83.3b</td>
<td>(118)</td>
</tr>
<tr>
<td>Phyllostachys bambusoides</td>
<td>120.2</td>
<td>(243)</td>
</tr>
<tr>
<td>Phyllostachys edulis</td>
<td>120.9</td>
<td>(243)</td>
</tr>
<tr>
<td>Phyllostachys lithophila</td>
<td>96.5</td>
<td>(243)</td>
</tr>
<tr>
<td>Phyllostachys makinii</td>
<td>151.5d</td>
<td>(243)</td>
</tr>
<tr>
<td>Phyllostachys makinii (1-year crop)</td>
<td>127.6a</td>
<td>(47)</td>
</tr>
<tr>
<td>Phyllostachys makinii (mature)</td>
<td>133.2d</td>
<td>(47)</td>
</tr>
<tr>
<td>Phyllostachys makinii</td>
<td>139.0</td>
<td>(47)</td>
</tr>
<tr>
<td>Phyllostachys nigra var. henonis</td>
<td>110.2</td>
<td>(243)</td>
</tr>
</tbody>
</table>

**a** Calculated by the authors from data in Table XVII by dividing average length by average width.

**b** An approximate figure calculated by the authors by dividing the arithmetical average of maximum and minimum length by the arithmetical average of maximum and minimum width, as reported in Table XVII.

**c** Calculated by the authors as 125.5.

**d** Calculated by the authors as 166.7.
The figures of Table XIX may be compared with those for some common materials in Table XX.

### TABLE XX

LENGTH/WIDTH RATIOS FOR VARIOUS FIBERS

<table>
<thead>
<tr>
<th>Wood</th>
<th>Fiber Length (mm.)</th>
<th>Length/Width Ratio</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coniferous:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pine</td>
<td>4.521</td>
<td>91</td>
<td>(47)</td>
</tr>
<tr>
<td>Fir</td>
<td>3.26</td>
<td>66</td>
<td>(47)</td>
</tr>
<tr>
<td>Hemlock</td>
<td>4.458</td>
<td>100</td>
<td>(47)</td>
</tr>
<tr>
<td>Broadleaf:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alder</td>
<td>1.408</td>
<td>51</td>
<td>(47)</td>
</tr>
<tr>
<td>Eucalyptus</td>
<td>1.104</td>
<td>63</td>
<td>(47)</td>
</tr>
<tr>
<td>Conifers</td>
<td>---</td>
<td>63.0</td>
<td>(243)</td>
</tr>
<tr>
<td>Sugar cane</td>
<td>---</td>
<td>100.0</td>
<td>(243)</td>
</tr>
<tr>
<td>Rice straw</td>
<td>---</td>
<td>80.0</td>
<td>(243)</td>
</tr>
</tbody>
</table>

It may be seen that the tabulated fiber lengths of bamboos fall between those of coniferous trees and those of the broadleaf woods, and that the length/width ratio of bamboo fibers appears to be much higher than that of wood fibers. These facts would indicate that very satisfactory paper can be made from bamboos.

It will be noted that several discrepancies exist among fiber measurements conducted by various workers. Some of these discrepancies may be due to errors in authentication of the bamboos, differences in the maceration procedures employed, variations of fiber sizes throughout the length of the culm, and/or errors in the sampling method. Because of this
it would be desirable to ascertain fiber lengths of the various bamboos in a fully reliable manner. A suggested program for fiber length determinations has been submitted previously (July 11, 1952). A copy of this program is included in Appendix II.

In general, it may be said that the fiber length tends to increase with the height of the culm. The fibers are found to be longer in the central part of the culm than in the basal section; however, the fiber length begins to decrease as the tip of the culm is approached. The magnitude of this variation differs greatly among species, but the same general pattern appears to be followed in most cases. The width of bamboo fibers tends to decrease continuously with the height of the culm. Both fiber length and width appear, in general, to vary in about the same manner through the culm wall; the fibers are longest and widest in the most interior portion of the wall. (170, 243, 270) (See also 176.)

Sigematu (229) conducted fiber-length studies on nine species of bamboo, representing the genera *Phyllostachys*, *Arundinaria*, *Semiarundinaria*, *Chimonobambusa*, *Sasa*, and *Bambusa*. The results are stated briefly here.

1. The difference between maximum and minimum fiber length is far greater than that of the broad-leafed trees and greatly resembles that of the coniferous trees. The difference between fiber thicknesses is much less than that between the fiber lengths.

2. The fibers are short at the foot of the stem and gradually increase their length with the stem height; however, the length again decreases at the upper end of the stem. The fiber thickness, on the contrary, gradually decreases from the foot to the top. Therefore, the variation in fiber lengths almost coincides with that of internode lengths, and the variation of fiber thickness with that of stem diameter.

3. When the stem wall is divided into three parts, it is found that fibers are longest at the middle and shortest at the outer
sections. No distinct tendency is followed in variation of length through the culm wall.

4. No specific correlation exists between the length of fibers and the thickness of the stems. Although the stem of Bambusa nana var. normalis is far more slender than that of Phyllostachys edulis (P. mitis) or P. bambusoides, it bears the longest fibers of the three, and while the fiber thickness of Chimonobambusa quadrangularis is the greatest of those studied, its culm diameter is about the same as that of B. nana var. normalis.

5. Within the same species or varieties there is positive correlation between the development of the stem and the fiber length.

6. The length/width ratio for the fibers almost corresponds to the variation of fiber length with stem height. However, the length/width ratio is smaller at the base than at the end of the stem. It is largest in the genus Bambusa.

7. The variation of fiber length is the largest at the part of the stem where the fibers are longest.

(3) Various Pulping Processes. Practically every known pulping method has been attempted with various species of bamboo. Results generally have been encouraging, although some processes naturally have proved more economical and more appropriate than others. The pulping experiments discussed in the literature are reviewed here, whether feasible or not.

(3.1) Mechanical Pulping. Although exhaustive investigations have not been made, mechanical pulping of bamboo is generally considered impractical and is probably the poorest of the methods discussed. (75, 186) Contrary to the opinion of most other investigators, W. L. Hendrix of the Herty Foundation Laboratory believes (as a result of tests on a small sample) that bamboo groundwood shows promise for newsprint and other uses.
(3.2) Soda Process. Pulping of bamboo by the soda process has proved generally successful, although results in this country have not been so good as those obtained in some foreign countries. In conjunction with Raitt's "fractional digestion" process, the soda method is quite widely used in India. The objection to the straight soda process advanced by Raitt (201) is that pectous material, present in a considerable quantity in bamboo, tends to gelatinize at digestion temperatures and form a coating over the fibers, inhibiting digestion and rendering the pulp difficult to wash. Bamboo soda pulp has also been found somewhat difficult to bleach, compared to pulp produced by the sulfate process. Fester and Maidana (99) found that the use of KOH and $\text{K}_2\text{CO}_3$ gives a somewhat higher yield than the straight soda process.

The results obtained by various investigators using the soda process to pulp bamboo are summarized in Table XXX of Appendix II. In most cases, quantitative data on the mechanical properties of the paper produced from these pulps were not reported.

(3.3) Sulfate Process. This method of pulping bamboo generally has been considered best from the standpoints of yield, bleachability of pulp, and the strength of paper produced. Consequently, a considerable amount of research has been conducted using this process, including the pulping of *Guadua paraguayana* (183) (Patettor, et al.), *Dendrocalamus longispatus* (74) (Bhargava and Singh), "Keitiku" (261) (Tutiya and Kato), and *Phyllostachys bambusoides* (52, 54, 144) (Arthur D. Little, Inc., and the Herty Foundation). The results of these experimental pulpings are valuable in that, when considered collectively, they give an indication of the effect of pulping conditions on the pulp produced.
from various bamboos. They also can serve as a guide for possible future work to determine the most desirable conditions for preparing bamboo pulp. A brief summary of the results obtained by various workers using the sulfite process is included in Appendix II. (See also 11, 28, 71, 90, 202.)

(3.4) "Gruco" Process. It appears to be generally true that pulping results obtained with the alkaline processes in India, China, and Japan are better than those obtained in this country at the present time. One explanation for this discrepancy may be that, in these countries, the material is digested with a liquor of somewhat lower concentration than is usually used here, and the digestion is generally less drastic. The results obtained from the "Gruco" process (29), a modified sulfate process developed in Sweden, appear to bear out this conclusion. The "Gruco" process has been applied to bamboo, wheat straw, sabai grass, and bagasse. In principle the method consists of three steps:

a. The choice of a cooking liquor having a lower content of NaOH and Na₂S than cooking liquors for sulfate digestion of wood, and preferably composed of 75 to 80 g. of NaOH plus 12 to 15 g. of Na₂S per liter of liquor for bamboo.

b. A total cooking period, i.e., the period for bringing the charge to digestive temperature plus the digesting time up to the degasification of the charge, not to exceed four hours.

c. The reduction of the digesting temperature, compared with that employed in the sulfate digestion of wood, to a maximum of 160° C and preferably to a temperature range between 140° and 150° C.

The bamboo used in this investigation was described only as Hill Bamboo from British India. It was digested at 158° C and yielded about 62
per cent of unbleached pulp. Screening of the pulp proved unnecessary, and the pulp was passed directly to the beater. This pulp proved to be more difficult to beat than Swedish sulfate pulp and required a good beating of about one and one-half to two hours before proper felting was obtained. Quantitative results of tests on the paper were: Schopper breaking length, 8,750 meters in both directions; Schopper double folding, 755 to 800 times; Mullen, 6.0 kg/cm² for 80-g. paper, 3.8 kg/cm² for 50-g. paper.

(3.5) Sulfite Process. This process has not found a particularly large application in bamboo pulping. It is considered by some to be impractical for use in the tropics (57, 245). Moreover, early investigation showed that sulfite bamboo pulp is very difficult to bleach (57, 58, 245); however, this difficulty has been partially overcome. Jardine (120, 121) and Jardine and Nelson (122, 123, 124) have made several contributions to the improvement of sulfite pulping of bamboo, including both mechanical treatment of the raw material and modification in the cooking process. The unbleachable yellow color of the sulfite pulp may be due to an excess of free sulfurous acid in the digester liquid, which is thought to char the fiber. Jardine and Nelson (124) claim to have overcome this difficulty by using, instead of calcium bisulfite, a base which yields a soluble sulfite, e.g., sodium or magnesium, so that a large excess of sulfurous acid is not required to keep the salt in solution. The sulfur dioxide evolved during the cooking process is allowed to escape freely through an exhaust kept open throughout the digestion process. It is claimed that with this treatment a yield of greyish-white pulp is obtained, which amounts to about 50 per cent of the raw
material. This pulp can be readily bleached to a full white. A later modification of this process, developed in 1915 by Jardine and Nelson, gave directions for preparing a magnesium bisulfite solution containing the proper proportions of dissolved base and sulfurous acid. This process can be controlled so that there is practically no volatilization of sulfur dioxide, and, consequently, so that no provision for gas liberation need be made. The use of $\text{MgSO}_3$ and $\text{Mg(HSO}_3\text{)}_2$ has also been found satisfactory by Tutiya, et al. (256, 258), and the results obtained from the use of a mixture of $\text{NaOH}$ and $\text{Na}_2\text{SO}_3$ have been reported by other workers (30, 97).

Contrary to the findings of previous investigators, Schmidt (225), conducting investigations in 1914, found that sulfite pulping of bamboo under relatively mild conditions (14 hours at three and one-half atmospheres with 2.8° Baumé calcium bisulfite solution) yielded 51 per cent of soft, dark pulp, bleachable with 12 per cent bleaching powder. Another modification of the sulfite process was developed by Richter (219) in 1932. In this procedure the material is partially cooked in a regular sulfite solution and subsequently treated with an alkaline liquor to complete the fiber liberation.

Although alkali processes are predominantly employed in India, one large mill, operated by the India Paper Pulp Company at Naihati, has found the acid sulfite process satisfactory for the production of paper from bamboo (14, 59).

(3.6) Other Pulping Processes.

(3.61) Modifications of Basic Processes. Many modifications of the basic chemical pulping processes--soda, sulfate, and
sulfite—have been employed with bamboo. The black liquor from soda or sulfite wood pulping has been employed for dissolving the incrusting substances of pectocellulosic materials, including straw, esparto, etc., as well as bamboo (92). Several two-stage alkaline methods have been evolved. Traquair (251) patented a system which specifies cooking the raw material in an alkaline solution of dilute concentration first at a low temperature and pressure and then at a much higher temperature and pressure, retaining the original weak liquor. Karnik and Sen (128) developed a two-stage process consisting of a soda cook for two hours at 20 psi and a Kraft cook for six hours at 60 psi; this treatment was applied to *Bamboo arundinacea* and *Dendrocalamus strictus*.

Another modification of the alkaline methods was employed by Hoyer (119), who subjected the raw material to a vacuum treatment, cooked it in an alkaline medium under pressure, suddenly released the pressure and continued the treatment under atmospheric pressure until disintegration was complete. Okochi (178) found that the addition of an alcoholic extract of oak to the alkaline liquor prevents decomposition of the fiber and lessens the fiber loss. Milne (165) influenced the reaction between the alkali and the digested material by passing an uninterrupted electric current through the walls of the digester and proportionally in shunt through its contents. Kyi (138) produced satisfactory pulp by employing \((\text{NH}_4)_2\text{S}\) in place of \(\text{Na}_2\text{S}\) in a modification of the sulfate process.

A mechanical modification of the sulfite process, developed by the de la Rosa Corporation (220), consists of compacting the raw material to remove essentially all of the air (e.g., by forcing liquid, gas, or powder through the substance) and feeding it to the digestion zone, thus preventing the formation of \(\text{H}_2\text{SO}_4\) from \(\text{H}_2\text{SO}_3\).
Processes Using Nitric and Other Acids.

The nitric acid method of pulping has produced a good quality pulp from bamboo (86, 259, 260); yields of crude pulp by this process, however, are considerably lower than those from other processes, ranging from around 20 to 40 per cent. Moreover, the nitric acid process is not economical at present because it is impractical to recover the digesting liquor (86). Weak solutions of other mineral acids have been employed by Wohl (281). In one case he used a concentration such that the hydrolytic effect was less than that of a 0.5 per cent solution of HCl at 100° C. The method suggested by Eggert (93) consists of two procedures: an initial treatment with weak acid liquor to hydrolyze noncellulosic carbohydrates and subsequent treatments with dilute alkali and chlorine as adapted from the Pomilio process.

Pomilio Soda-Chlorine Process. This technique, patented in 1938 by Umberto Pomilio (194), consists of an alkali treatment followed by a chlorination treatment. The alkali reaction is conducted in a closed vessel at 100°-150° C under 20-50 psi pressure and the chlorination reaction in an open vessel at a temperature not exceeding 65° C. The alkali employed is a 2.4 per cent solution using 4.6 parts of solution to one part of raw material. After the chlorine treatment, the material is treated with alkali of 0.1-10 per cent concentration at a temperature up to 100° C. The Pomilio process has been used with bamboo by several workers (221, 273), but little information on the results is available. In 1939 construction was begun on a pilot plant at Orpington, Kent, England, where a wide variety of materials, including bamboo, was to be treated by the Pomilio process on a semi-industrial scale (46).
The Pomilio process is probably an outgrowth of the de Vains process (87) which is, in turn, simply an industrial application of Cross and Bevan's classic method for the isolation of pure cellulose.

(3.64) Lime Process. The lime pulping process, which might be called a modern application of the ancient Chinese pulping method, was patented by McRae and Malcolmson in 1911 (157). It consists of boiling the material from 4 to 16 hours at a pressure of 15-100 psi in water containing lime only; the quantity of lime varied from 5 to 25 percent of the dry weight of the raw material. It was found (58) that, although the process was inexpensive, the product was brown in color and was in no condition for bleaching; Lymn and Leyst (146), however, found that further refining with caustic produced a pulp which could be bleached with "chloride of lime" solution. Lymn further reported (145) that partial digestion of the material with lime produced "semi-pulp" or "quarter-stuff" which could be pressed into cakes to lessen transportation costs and later could be converted into soda pulp with a relatively small quantity of NaOH at low pressure.

(3.65) Miscellaneous Processes. Work on bamboo pulping has been conducted on a small scale using many methods, including the Tingle polysulfide process (90, 239) and a variation of it (79), the Muskau process (171), sodium xylenesulfonate (139), water (156), and solutions of zinc salts (160). Quantitative data on these processes are not available. (See also 3, 13, 48, 130, 215, 255, 283.)

(4) Suitable Pulping Procedures.

(4.1) Comminution. Initial operations for cutting and crushing bamboo in preparation for pulping may be divided into four general classes (58).
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a. The stems are passed through crushing rollers; with the material held in the nip of the last pair of crushing rollers, the fibers are pulled apart by drawing rollers.

b. The stems are subjected throughout their whole length to a simultaneous rubbing and crushing action. The machine used consists of two or more channelled rollers rotating at different speeds.

c. The stems are crushed and disintegrated with rollers and then cut into convenient lengths for passing to the digester.

d. The stems are first cracked by passing them between rollers and are then split in two longitudinally with a knife. The split portions are submitted to crushing and disintegrating rollers and are finally cut into portions of a convenient length.

One of the most successful comminuting devices for bamboo is Jardine's (15, 16, 120, 122, 123), which follows in principle the third method listed above. In his method the canes are thoroughly flattened and crushed by circumferentially grooved rolls and are cut into suitable lengths with a rotating knife. Other inventions developed for comminuting bamboo are a hammer mill by Leyst-Kuchenmeister (141), a rod mill by Wells (278), and a shredding apparatus adjustable for shred width by Williams (279).

4.2 Bleaching. A two-stage bleaching process, following the alkaline-cooking stage, has been applied to Phyllostachys edulis (pubescens) with considerable success. (125) The bleaching with NaOCl, followed by a chlorine-water bleach, is facilitated by adding dilute sulfuric acid and by increasing the temperature. Two-stage bleaching produces superior results on the darker pulps, although for
lighter pulps the double and single bleachings have showed no significant difference. (See also 36, 156, 158.)

(4.3) Digestion. One method found suitable for the digestion of bamboo and similar material consists simply of a cascade of digesters in a closed ring. Each digester is charged in turn, and the digesting liquor, after use in any one digester, is passed to the digester next-but-one lower in the cycle of operating sequence (76, 82). This method, a semicontinuous treatment of the raw material, has been applied to soda, sulfate, and sulfite pulping. Another device, patented by Schauflerberger (223), provides the digester with a circulating pump arranged so that, while the circulation of the liquor in the digester is for the most part directed upward, there is also a downward circulation in the uppermost part of the digester. Since bamboo is somewhat more resistant to penetration than wood, some type of circulation of the digesting liquor is desirable. In another digester system, discussed by Sindall (235), the cooking liquor is passed through the stock and through an outside circulating system heated by high-pressure steam. The volume of liquor in the digester is not increased by condensation, and the recovery is much more economical.

The digestion adaptation which has found the widest application is termed "fractional digestion." This method was first patented in 1912 (205) by William Raitt, and improvements were patented in 1915 (208) and 1920 (211). It has been widely used in conjunction with the alkaline pulping processes in India (14, 59, 73, 111, 182, 202, 203, 207, 209, 271). Its many advantages over conventional processes include not only the reduction of NaOH consumption, cooking temperature and pressure, bleach
consumption, and the amount of spent liquor but also a three per cent increase in the yield of bleached pulp. The considerations involved in the development of this process are reviewed here briefly (204, 214, also reported in 127):

The plant substance of bamboo falls into four different chemical groups. Each has one substantially basic substance which reacts in a distinct and special manner to the action of the solvents and temperature and which manifests individual color reactions; their particular characteristics follow:

Group 1: This group contains starch and its secondary transformation products, including sugars, with small amounts of tannin and water-soluble gums, earth salts and coloring matter. The bulk of the constituents is secondary starches and sugars soluble in cold water. This group includes all of the neutral substances which are soluble in water at 100°C.

Group 2: This group is composed of all the acid bodies that are soluble in one per cent NaOH at 100°C and pectins with small amounts of fats, waxes, resins, gums, and earth salts insoluble in hot water.

Group 3: This group includes lignins and acid bodies soluble in four per cent NaOH solution at 130°C. In analysis they are separated from cellulose by the Cross and Bevan chlorination method.

Group 4: The main constituent of this group is cellulose, the insoluble residue that results from the action of the solvents listed above. It exists in three forms: alpha, beta, and gamma.

According to Raitt, during digestion Group 1 produces a dye which stains the pulp, is not wholly washable, and is not entirely discharged by an excess of bleach. Group 2 produces a malignant, nonwashable, and permanent dye on the pulp, and, where these dyeing reactions are allowed to take place, the most efficient bleaching results only in a cream color.

Raitt has drawn five conclusions from his findings:

a. Soluble compounds in bamboo fall into several different groups, each with a strongly marked degree of solubility.

b. The alkaline solutions of Groups 1 and 2 are inimical to bleaching; that of Group 3 is innocuous.
c. Groups 1 and 2 are soluble in one per cent NaOH at 100° C, while Group 3 is not wholly soluble in a four per cent solution of NaOH at a temperature less than 130° C.

d. Although Group 1 is wholly soluble in hot water, it can be extracted more quickly along with Group 2; the amount of NaOH lost through reactions with Group 1 is more than compensated for by the saving in time.

e. Total cooking time after 100° C is reached need not exceed three hours for grasses and five hours for bamboo.

Raitt suggests a fractional or two-stage digestion method in which, first, the components of Groups 1 and 2 are removed by treating the bamboo with the spent liquor from a previous cook; then the bamboo residue is treated with a stronger caustic solution. Although the alkaline solutions of Groups 1 and 2 cause a staining of the pulp which is not easily removed by bleaching, when these starches and pectins are removed prior to delignification, the pulping action takes place in a nonstaining medium, producing an easy-to-bleach pulp.

(5) Dissolving Pulp. The term "dissolving pulp" is generally used to describe the highly purified pulps employed for the manufacture of such materials as rayon, cellophane, cellulose plastics and lacquers, fillers for urea resins, facial tissues, and photographic films. In manufacturing rayon and cellophane, the pulp is dissolved and the cellulose is then regenerated, which gives rise to the name "dissolving pulp." The requirements of dissolving pulps vary with the product to be manufactured. Table XXI shows representative requirements.

Joglekar (127), conducting investigations on an unidentified species of bamboo obtained from Fort Meyers, Florida, noted that the main difficulty involved in converting bamboo into dissolving pulp lay in its high pentosan content. It was found that the pentosan content of the Kraft
TABLE XXI
CHEMICAL CHARACTERISTICS OF A SUITABLE VISCOSE PULP (127)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>α-cellulose</td>
<td>Greater than 88.0 per cent</td>
</tr>
<tr>
<td>Pentosan content</td>
<td>Less than 5.0 per cent</td>
</tr>
<tr>
<td>Lignin content</td>
<td>Less than 0.15 per cent</td>
</tr>
<tr>
<td>Ash content</td>
<td>Less than 0.15 per cent</td>
</tr>
<tr>
<td>Alcohol-benzene solubles</td>
<td>Less than 0.5 per cent</td>
</tr>
<tr>
<td>Viscosity (TAPPI)</td>
<td>1 to 25 centipoises</td>
</tr>
<tr>
<td>Brightness (Higgins)</td>
<td>Greater than 85.0 per cent</td>
</tr>
</tbody>
</table>

Pulp could not be reduced below seven per cent, even with drastic purification treatments including hot and cold caustic soda extraction, acid hydrolysis followed by caustic extraction, and chlorination followed by caustic extraction. Better results were obtained by prehydrolyzing the bamboo chips, using two per cent sulfuric acid at 110° C for two and one-half hours, and following this with a Kraft cook at 165° C; the mixture is 20 per cent chemical calculated as Na₂O with a sulfidity of 33 per cent. The pulp produced by this method required no purification in addition to that normally required for a three-stage bleach conducted by conventional methods. Its analysis was typical: α-cellulose, 96.5 per cent; pentosan, 3.7 per cent; and ash, 0.4 per cent. The TAPPI viscosity was 25 centipoises. The pulp, therefore, met all the specifications required of a viscose-grade pulp except for the high ash content.
The Forest Research Institute at Dehra Dun, India, has experimented with preparing viscose pulp from *Ochlandra travancorica*, obtaining pulp of 89-90 per cent α-cellulose and up to 0.3 per cent ash content (60). Estape (97) patented a process in 1931 for the manufacture of a pulp suitable for rayon production. In the opinion of Hebbs (109), bamboo and other high-pentosan materials can be utilized for rayon production if it is not in open competition with wood pulp. The presence of a large percentage of pentosans in dissolving pulp makes filtering the viscose difficult and so leads to increased production costs.

(6) Conclusions on the Manufacture of Pulp from Bamboo.

From the foregoing information it may be seen that satisfactory paper pulp can be manufactured from several species of bamboo. In general, the sulfate process has been, thus far, the most suitable pulping method, particularly when modified by the use of Raitt's "fractional digestion" process. The soda process has produced satisfactory bamboo paper; however, results have not been generally so good as those obtained from the sulfate process. Bamboo sulfite pulp is very difficult to bleach, and yields are not as high as those obtained from other processes. It seems apparent that a very cheap dark pulp, suitable for wrapping paper, board, etc., can be made from bamboo by the lime process. At the present time the manufacture of dissolving pulp from bamboo does not appear feasible; however, development of better methods for reducing the pentosan and ash contents of the pulp could render dissolving pulp production practical.

Much investigation remains to be made on the economic aspects of bamboo pulping. To date no experiments have been conducted on a scale that could provide a conclusive comparison of the cost of bamboo pulping.
with that of wood pulping. Furthermore, it is thought that considerable
eperimentation on pulping conditions should be made in order to deter-
mine the optimum methods for pulping various species of bamboo. Species
other than those heretofore employed should also be tested for pulping
properties. Some suggestions relative to this have been made previously
in a progress report dated August 12, 1952. An excerpt from this report
is included in Appendix II. In addition, growth factors such as the
yield of cellulose per unit area for particular species, the optimum har-
esting methods, and the most suitable form and methods of transportation
to the mill should be determined.

c. Other Uses. The uses to which bamboo can be applied are
almost unlimited; bamboo can, and in some cases does, supply practically
all human needs. A representative list of some of the uses of bamboo
may be seen in Table XXXI in Appendix II. Some of the more interesting
and important uses will be mentioned here in more detail.

(1) Food. As previously noted, the young shoots of some
species are considered a delicacy by the natives of Oriental and other
countries and are used in relatively large quantities in this country as
an ingredient of Chinese and Japanese dishes. The leaves of many species,
both fresh and silaged, make excellent fodder for farm stock (27, 63, 77,
80). It has been the practice in some parts of Jamaica to cut down the
culms and burn over the clumps at the end of the October season during
periods when a drought in the spring is feared. The rhizomes will then
produce a rich mass of vegetation, supplying fodder throughout the driest
weather (27). A silage prepared from "Indian Cane" in Rhodesia was found
to have the following composition: water, 70 per cent; fat, 0.7 per cent;
crude protein, 1.6 per cent; true protein, 1.00 per cent; carbohydrates, 14.9 per cent; fiber, 11.0 per cent; and ash, 1.8 per cent (77). Some species (Pseudosasa japonica, Phyllostachys bambusoides, and several others) furnish food for animals such as pandas (9).

(2) Nails and Phonograph Needles. Limaye (142) found that bamboo nails (more strictly, pegs) hold as well as iron nails, although the bamboo nails require predrilling of the wood. Very satisfactory phonograph needles have been manufactured from bamboo slivers. The slivers are heated in oil at 340° F. and tumbled in barrels containing sawdust, which removes excess oil and polishes the slivers. They are then ready to be pointed and used. (45).

(3) Fuel. Piatti (189) reports that a Diesel fuel has been manufactured from an unstated species of bamboo. Typical constants of this fuel are: d_15^° 0.921; flame point, 55°; viscosity at 20° C, 1.1 Engler degrees, and at 55° C, 1.0 Engler degrees; water content, 0.35 per cent; total acidity, 0.45 mg. KOH/g.; ASTM boiling point range, 140°-250° C; nondrying oily residues, 1.5 per cent.

(4) Construction. Perhaps the most important use to which bamboo could be put in this country, other than in the manufacture of paper, is that for light-but-strong construction. Ladders, scaffolding, temporary trestlework, and many other forms of construction could be more portable and more easily handled by using bamboo culms. It is interesting to note that many very large structures have been built in Oriental countries employing bamboo culms either as permanent members or as a temporary framework while steel construction was under way. As early as 1917 a temporary bamboo trestle, 125 feet high with a span of
400 feet, was erected near Miyaroshita, Japan, and used until a steel railroad bridge could be completed (20). Although detailed information was not obtained, it is supposed that the bamboo members were either lashed together according to the ancient Oriental practice or drilled through and fastened with wooden or bamboo pegs.

The application of modern fastening methods to the joining of bamboo culms shows promise of greatly increased speed and applicability of bamboo construction. A very satisfactory method developed recently (265) requires three procedures: the ends of each section of the bamboo culms are reamed out on a slight taper; a thin sheet of a plastic adhesive and an aluminum plug, threaded internally and shaped to fit closely into the reamed seat, are placed over the tapered opening, and the plug and plastic are forced in under pressure; induction heating seals the plastic to the metal and the bamboo, forming an almost inseparable bond. In another arrangement, threaded collars are made to fit over the shaped ends of the bamboo sections and the sections are joined by lightweight union connectors.

Provision is also made for transverse-type fittings. This type of fitting would lend itself readily to mass production. The only obvious drawback is the need for properly seasoned culms which would not split. It is believed that well-seasoned medium and large culms joined in any of these fashions could compare favorably with aluminum for practically all types of light-but-strong construction, particularly those of a temporary nature.

(5) Miscellaneous. For the past several years, the United States Department of Agriculture has recommended that individual
farmers grow about one acre of bamboo for the many uses to which it can be applied on the farm. Strong, easily constructed windbreaks and snow fences can be quickly constructed from either whole or split bamboo culms. With a small grove of bamboo available, the procurement of plant stakes, bean poles, fishing poles, and similar items would be a very simple matter. The material is also useful for open constructions, such as shade houses, poultry coops, and fruit and vegetable crates.

A market exists in this country for all types of bamboo furniture and household ornaments; at present manufacturers are using primarily imported material. In addition to the articles manufactured in this country from imported bamboo, large quantities of finished items are brought in, chiefly from Oriental countries. Since practically all the species which flourish in the Orient can be grown without difficulty in this country, it appears that a large portion of this market could be supplied by American-grown bamboo and American-made articles.

E. Economics of Bamboos

1. Economic History

Markets for bamboo products have existed in the United States for many years, although the uses which furnish large-volume markets are comparatively few in this country as compared to uses in countries where bamboo is native. The major proportion of bamboo products and raw bamboo used in the United States has been imported. Several reasons are cited for these imports: for some uses, consumers require a specific variety in large volumes which cannot be supplied by the relatively small domestic production; some manufacturers consider locally grown material inferior to imported material of the same species; and some products can
be imported at prices lower than those of the same products manufactured
domestically because of lower labor costs in Oriental and South American
countries. As a generalization, it may be said that the consumption of
domestically produced raw bamboo has been negligible in comparison with
that of imported material. Some bamboo products—furniture, window-
shades, ornaments, split-bamboo fishing rods, etc.—are manufactured in
this country (from imported raw material) in relatively large quantities,
although a very large percentage of these finished products is imported
for the reasons mentioned above. Edible canned bamboo shoots have been
imported into this country from Japan and China for a number of years.

Because most of the bamboo consumed in this country is imported, a
good picture of the economic history of the United States bamboo trade
may be obtained from a study of bamboo imports for consumption over past
years. This information was surveyed, using data obtained from Department
of Commerce Report FT-110, United States Imports of Merchandise for Con-
sumption, and from contacts with exporters in the Orient. Report FT-110
tabulates import information on rough bamboo sticks (defined as "no fur-
ther advanced than cut into lengths"), split bamboo, and bamboo bags and
baskets. Information on other bamboo products, such as furniture, window
shades, ornaments, shoots, etc., was not tabulated separately. These
products were included with manufactures from other materials, such as
rattan, osier, and willow. Figures on bamboo in forms other than rough
sticks or split and on products other than bags and baskets are therefore
not included. Statistics on the volume of canned bamboo shoots imported
for the years 1949-51 were obtained from Japanese exporters.
Figure 9 illustrates in graphical form the value of United States imports of bamboo for consumption over the period 1930-51 inclusive; the relative values for rough sticks, split bamboo, and bamboo bags and baskets are shown. The general trend of these data shows a rapid increase in the value of bamboo imports beginning about 1939, broken by the beginning years of World War II. However, a complete market picture cannot be obtained from a study of value alone because of the rapid rise of over-all price indices over the past few years. Figures 10 and 11, therefore, show the yearly figures of volume imported and calculated average price for split bamboo and bamboo bags and baskets, respectively. The Department of Commerce publication referred to does not regularly report volume figures on imports of rough bamboo sticks. In 1943 and 1944 rough stick imports are listed as 855,000 pounds and 1,155,000 pounds, respectively, with total values of $35,000 and $87,000; these figures can be broken down into average prices of 4.1 cents per pound in 1943 and 7.5 cents per pound in 1944. The prices are all f.o.b. port of origin; import duties and transportation costs must be added to obtain the total value of goods delivered in this country.

The following rates of import duty* apply to these three forms of bamboo:

- Rough sticks--free,
- Bamboo Bags and Baskets--50 per cent (1930 Tariff Act), 25 per cent (Mexico), 20 per cent (Cuba),
- Split Bamboo--5/8 cents per pound.

Figure 9. Imports of Bamboo for Consumption.
Figure 10. Imports of Split Bamboo for Consumption.
Figure 11. Imports of Bamboo Bags and Baskets for Consumption.
Phase Report No. 3, Project No. 177-170

Freight cost has been estimated at about 25 per cent of the cost f.o.b. port of origin. The freight cost has varied, however, from about $6.00 to $25.00 per volumetric ton (36 cubic feet) in the last 10-15 years.

Table XXII presents the data plotted in Figures 9, 10, and 11 together with the countries supplying each form during each calendar year.

Unit price statistics for poles in 1952 as quoted by importers in the New York area are presented in Table XXIII.

The volumes of canned bamboo shoots imported into the United States from Japan for the years 1949 through July, 1952, are shown in Table XXIV. These figures do not include shoots imported from China; however, the 1951 figure is considered as the total imports for that year.

The bulk of the bamboo imported into this country in the form of untreated sticks may be divided into two main classes: canes imported for unmanufactured fishing poles, which are almost exclusively Phyllostachys aurea ("fishpole bamboo"); and canes imported for the manufacture of laminated fishing rods and for use as rug poles and handling poles, most of which is Tonkin cane (Arundinaria amabilis).

It may be seen from Table XXII that, previous to World War II, rough bamboo canes were supplied to this country almost exclusively by Japan, with China entering the market in 1940. During the years 1936, 1937, and 1938 no shipments of rough canes were received in this country; beginning in 1939, a sharp rise in the total value of imports of rough sticks began and was maintained until the beginning of World War II.

At the beginning of the war supplies of material from Japan and China were cut off, with a resulting drop in imports through 1944. During the
TABLE XXII

BAMBOO--IMPORTS FOR CONSUMPTION*  

<table>
<thead>
<tr>
<th>Year</th>
<th>Value (Thousands of Dollars)</th>
<th>Average Price (Cents/Pound)</th>
<th>Chief Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rough Sticks:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1930</td>
<td>11</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>1931</td>
<td>18</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>1932</td>
<td>31</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>1933</td>
<td>47</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>1934</td>
<td>86</td>
<td>---</td>
<td>Japan</td>
</tr>
<tr>
<td>1935</td>
<td>43</td>
<td>---</td>
<td>Japan</td>
</tr>
<tr>
<td>1936</td>
<td>0</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>1937</td>
<td>0</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>1938</td>
<td>0</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>1939</td>
<td>268</td>
<td>---</td>
<td>Japan</td>
</tr>
<tr>
<td>1940</td>
<td>544</td>
<td>---</td>
<td>Japan, China</td>
</tr>
<tr>
<td>1941</td>
<td>475</td>
<td>---</td>
<td>China, Japan</td>
</tr>
<tr>
<td>1942</td>
<td>34</td>
<td>---</td>
<td>India, Spain</td>
</tr>
<tr>
<td>1943</td>
<td>35</td>
<td>---</td>
<td>Mexico, India, Spain</td>
</tr>
<tr>
<td>1944</td>
<td>87</td>
<td>---</td>
<td>Mexico, India</td>
</tr>
<tr>
<td>1945</td>
<td>289</td>
<td>---</td>
<td>Mexico, India, Brazil</td>
</tr>
<tr>
<td>1946</td>
<td>1,101</td>
<td>---</td>
<td>China, India, Mexico, Brazil</td>
</tr>
<tr>
<td>1947</td>
<td>812</td>
<td>---</td>
<td>China, India, Brazil</td>
</tr>
</tbody>
</table>

(Continued)
TABLE XXII (Continued)

BAMBOO—IMPORTS FOR CONSUMPTION\(^a\)

<table>
<thead>
<tr>
<th>Year</th>
<th>Value (Thousands of Dollars)</th>
<th>Average Price (Cents/Pound)</th>
<th>Chief Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rough Sticks (Continued):</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1948 1,498 --- Japan, China, India, Brazil, Taiwan, Burma</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1949 883 --- Japan, China, Taiwan, India</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1950 701 --- Japan, India, China, Burma</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1951 580 --- Japan, Burma, India</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Split Bamboo:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Quantity (Thousands of Pounds)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1930 2,326 1.9 China, Hong Kong, Japan(^b)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1931 1,124 1.8 ---</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1932 746 1.7 ---</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1933 1,083 1.9 ---</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1934 998 1.8 Hong Kong, Japan, China</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1935 1,306 1.8 Hong Kong, Japan, China</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>1936 1,604 1.3 Hong Kong, China, Japan</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1937 1,339 1.3 Hong Kong, China, Japan</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1938 1,248 1.6 China, Hong Kong, Japan</td>
</tr>
</tbody>
</table>

(Continued)
### TABLE XXII (Continued)

**BAMBOO--IMPORTS FOR CONSUMPTION**

<table>
<thead>
<tr>
<th>Year</th>
<th>Quantity (Thousands of Pounds)</th>
<th>Average Price (Cents/Pound)</th>
<th>Chief Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Split Bamboo (Continued):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1939</td>
<td>374</td>
<td>2.1</td>
<td>China, Japan</td>
</tr>
<tr>
<td>1940</td>
<td>848</td>
<td>3.6</td>
<td>China, Japan, Hong Kong</td>
</tr>
<tr>
<td>1941</td>
<td>1,085</td>
<td>3.6</td>
<td>China, Hong Kong, Japan</td>
</tr>
<tr>
<td>1942</td>
<td>22</td>
<td>4.5</td>
<td>China</td>
</tr>
<tr>
<td>1943</td>
<td>0</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>1944</td>
<td>0</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>1945</td>
<td>0</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>1946</td>
<td>57</td>
<td>12.0</td>
<td>China, Trinidad</td>
</tr>
<tr>
<td>1947</td>
<td>1,116</td>
<td>8.2</td>
<td>China</td>
</tr>
<tr>
<td>1948</td>
<td>1,282</td>
<td>3.9</td>
<td>China</td>
</tr>
<tr>
<td>1949</td>
<td>666</td>
<td>4.2</td>
<td>China</td>
</tr>
<tr>
<td>1950</td>
<td>907</td>
<td>6.8</td>
<td>China</td>
</tr>
<tr>
<td>1951</td>
<td>635</td>
<td>5.8</td>
<td>China, Hong Kong, Japan</td>
</tr>
</tbody>
</table>

**Bamboo Bags and Baskets:**

<table>
<thead>
<tr>
<th>Year</th>
<th>Quantity (Thousands of Items)</th>
<th>Average Price (Cents/Pound)</th>
<th>Chief Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>1930</td>
<td>883</td>
<td>7.5</td>
<td>---</td>
</tr>
<tr>
<td>1931</td>
<td>900</td>
<td>6.6</td>
<td>---</td>
</tr>
<tr>
<td>1932</td>
<td>851</td>
<td>3.8</td>
<td>---</td>
</tr>
</tbody>
</table>

(Continued)
<table>
<thead>
<tr>
<th>Year</th>
<th>Quantity (Thousands of Items)</th>
<th>Average Price (Cents/Pound)</th>
<th>Chief Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>1933</td>
<td>726</td>
<td>3.7</td>
<td>---</td>
</tr>
<tr>
<td>1934</td>
<td>573</td>
<td>6.5</td>
<td>Japan, China, Hong Kong</td>
</tr>
<tr>
<td>1935</td>
<td>991</td>
<td>5.2</td>
<td>Japan, China</td>
</tr>
<tr>
<td>1936</td>
<td>1,456</td>
<td>5.4</td>
<td>China, Japan</td>
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<tr>
<td>1937</td>
<td>2,345</td>
<td>4.8</td>
<td>Japan, China</td>
</tr>
<tr>
<td>1938</td>
<td>1,496</td>
<td>4.8</td>
<td>China, Japan</td>
</tr>
<tr>
<td>1939</td>
<td>847</td>
<td>4.9</td>
<td>Japan, China</td>
</tr>
<tr>
<td>1940</td>
<td>1,017</td>
<td>6.8</td>
<td>Japan, China, Hong Kong</td>
</tr>
<tr>
<td>1941</td>
<td>1,082</td>
<td>5.6</td>
<td>Hong Kong, China, French Indo-China</td>
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<tr>
<td>1942</td>
<td>284</td>
<td>10.2</td>
<td>Mexico, Hong Kong</td>
</tr>
<tr>
<td>1943</td>
<td>1,131</td>
<td>20.7</td>
<td>Mexico</td>
</tr>
<tr>
<td>1944</td>
<td>2,510</td>
<td>20.6</td>
<td>Mexico</td>
</tr>
<tr>
<td>1945</td>
<td>3,613</td>
<td>16.8</td>
<td>Mexico</td>
</tr>
<tr>
<td>1946</td>
<td>3,207</td>
<td>18.1</td>
<td>Mexico</td>
</tr>
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</table>
**TABLE XXII (Concluded)**

**BAMBOO--IMPORTS FOR CONSUMPTION**

<table>
<thead>
<tr>
<th>Year</th>
<th>Quantity (Thousands of Items)</th>
<th>Average Price (Cents/Pound)</th>
<th>Chief Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>1947</td>
<td>2,320</td>
<td>12.6</td>
<td>Mexico, China</td>
</tr>
<tr>
<td>1948</td>
<td>4,674</td>
<td>9.7</td>
<td>Mexico, China, Hong Kong</td>
</tr>
<tr>
<td>1949</td>
<td>5,265</td>
<td>9.4</td>
<td>China, Mexico, Japan, Hong Kong</td>
</tr>
<tr>
<td>1950</td>
<td>9,716</td>
<td>9.3</td>
<td>Mexico, China, Japan</td>
</tr>
<tr>
<td>1951</td>
<td>5,407</td>
<td>13.1</td>
<td>Mexico, Japan, Hong Kong, China</td>
</tr>
</tbody>
</table>

*Data obtained from United States Imports of Merchandise for Consumption, U. S. Department of Commerce Report FT-110, Washington, D. C., 1930-51. The prices and values shown are f. o. b. port of origin. The data on bamboo products, other than on bags and baskets, are not tabulated separately.*

*b The sources are listed in the relative magnitude of shipments from these sources.*
TABLE XXIII

PRICES OF BAMBOO POLES IN 1952

<table>
<thead>
<tr>
<th>Length (Feet)</th>
<th>Diameter (Inches)</th>
<th>Price (Dollars per Hundred)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formosan Rug Poles\textsuperscript{a} (Probably \textit{Phyllostachys bambusoides}):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>7/8--1</td>
<td>8.75</td>
</tr>
<tr>
<td>12</td>
<td>1-1/4--1-1/2</td>
<td>14.00</td>
</tr>
<tr>
<td>15</td>
<td>1-1/2--1-3/4</td>
<td>30.00</td>
</tr>
<tr>
<td>Fishing Poles\textsuperscript{b} (\textit{Phyllostachys aurea}):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>---</td>
<td>4.10</td>
</tr>
<tr>
<td>12</td>
<td>---</td>
<td>5.70</td>
</tr>
<tr>
<td>14</td>
<td>---</td>
<td>8.00</td>
</tr>
<tr>
<td>16</td>
<td>---</td>
<td>11.40</td>
</tr>
<tr>
<td>18</td>
<td>---</td>
<td>14.80</td>
</tr>
<tr>
<td>20</td>
<td>---</td>
<td>17.40</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Rug poles must be straight and thick-walled, with practically no taper.

\textsuperscript{b} Fishing poles must be straight and have a sharp taper.
TABLE XXIV

IMPORTS OF BAMBOO SHOOTS FROM JAPAN

<table>
<thead>
<tr>
<th>Year</th>
<th>Volume(^a) (Cases)</th>
<th>Approximate Weight(^c) (Pounds)</th>
<th>Approximate Value(^d) (Dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1949</td>
<td>27,000</td>
<td>1,140,000</td>
<td>280,000</td>
</tr>
<tr>
<td>1950</td>
<td>35,000</td>
<td>1,470,000</td>
<td>360,000</td>
</tr>
<tr>
<td>1951</td>
<td>20,000</td>
<td>840,000</td>
<td>206,000</td>
</tr>
<tr>
<td>1952 (January-July)</td>
<td>30,000(^b)</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

\(^a\) Cases are made up of one of four assortments:
- 24 No. 2-1/2 cans,
- 36 No. 2 cans,
- 6 No. 10 cans,
- 48 7-ounce cans.

\(^b\) This figure is based on estimates by Japanese exporters.

\(^c\) The weight is assumed at 42 pounds per case.

\(^d\) The price per pound is estimated at 24.5 cents per pound, based on 1951 figures.
war small quantities of rough canes were imported from India, Spain, and Mexico; the relative scarcity of the material may have occurred because the desired species were unobtainable from these countries. In 1946, with the end of World War II and the re-entrance of China into the bamboo market, a sharp rise in imports of rough sticks occurred, and imports continued at a high level until the beginning of the Korean disturbance in 1950.

The value of split bamboo imports into the United States is considerably smaller than that of either rough canes or of bags and baskets. A large quantity of split bamboo is shipped from China, Hong Kong, and Japan directly to jobbers, rather than to large importers, since the material is considered partially manufactured and therefore dutiable. Much of this material is used in the manufacture of split-bamboo flyrods, although many flyrod manufacturers import the whole canes and perform the splitting operation at the factory. The bamboo used in these flyrods is almost exclusively Tonkin cane (Arundinaria amabilis), which is imported from China. Split bamboo of other species is imported in small quantity for manufacturing blinds, screens, and various ornamental items.

It may be seen from Table XXII that China has been by far the largest supplier of split bamboo to this country. During the war years 1943-45, after four years of continuously rising prices, imports of split bamboo ceased entirely because of disturbances in the Orient. In 1946, at the end of the war, a small quantity was again imported at a very high price, indicating a large demand which probably was due to exhausted supplies after three years of unavailability of the material. After 1946, imports
of split bamboo rose again to the prewar level, while the price of the material decreased below the 1946 value but remained higher than in prewar years. Imports continued at this level until the beginning of the Korean disturbance, after which they appear to have fallen off somewhat.

Figure 11 indicates that the volume trend of imported bamboo bags and baskets has increased from about one million items in 1930 to about six million items in 1951. The material has come from Japan, China, and Hong Kong predominantly. However, when the Oriental supply has been short or cut off, Mexico has entered the supply picture. This indicates that, when the price is high, Mexico can compete with the Orient, but when Oriental material is available on the market, Mexican material meets buyer resistance because of its higher price. The price per item for bags and baskets has shown an increasing trend with a peak during the period 1942-47; during this period Mexico was the primary exporter to the United States.

Bamboos of various species have been grown in this country for commercial sale for a number of years. The major volume uses have been for poles and landscape material, but the shortage of imported material created a demand for other uses during the war years. There are several relatively minor uses for the domestic material including plant stakes, ornamental construction, some sporting goods, and furniture and related manufactures. Landscape material and plant stakes are usually supplied by nurseries and material for poles and other uses from individual growers. The poles are usually handled by wholesalers who purchase the material, cure it, and sell it to retail outfits.
Most of the domestic producers have small acreages (1/4 to 2 acres) of various species of bamboo. However, there are several growers who have larger groves (five to ten acres) containing several species, and there is one 40-acre grove at Avery Island, Louisiana. In general, the growers have reported that during the war they were able to sell their bamboo at good prices.

The situation since 1946 has been confusing. That is, some producers reported that they could have sold more material if it had been available; others reported that the demand has been primarily a local one and that volume demands have decreased drastically.

Some of the producers in the North and South Carolina area reported that they have been selling bamboo in small quantities with a steady demand and an adequate supply. Others in that area have been able to sell very little of their produce.

Georgia and Florida producers have reported a steady demand, primarily for fishing poles, plant stakes, and novelty material. The supply has been considered adequate for the demand.

The operators in the Louisiana and southern Mississippi area reported that the demand for bamboo has been good and steady and that the demands for some uses are increasing.

One broker in Alabama reportedly handled most of the bamboo fishing poles produced in north Florida and Alabama. He bought several species but the trade desired Phyllostachys aurea. His yearly volume has been about 50,000 poles per year and his price to the grower has been from 8 to 12 cents per pole. After curing, the poles were sold locally to retail outfits. It was stated that the demand for these poles has been
steady and the volume could be doubled if the poles were available. In general, a problem exists in that producers are not aware of the markets and buyers do not know of the sources.

Bamboo landscape materials are handled as a stock item by numerous nurseries. These nurseries reported that the demand for this type of ornamental was good and that the supply was adequate with the exception of the fern-leaf dwarf types, e.g., the Variety disticha of Bambusa multiplex. The nurseries also reported that the demand for small lots of propagation material is increasing with Phyllostachys aurea being the most popular species.

The price for domestic material has generally varied with the availability of imported bamboo. For example, in 1942 through 1945 growers received about 10 cents per linear foot for Phyllostachys bambusoides two inches and over, and in 1951 about two cents per foot for this same size. The price of fishing poles (Phyllostachys bambusoides and Phyllostachys aurea) has ranged from about 75 cents per pole in 1942-45 to about ten cents per pole in 1952.

The price for the propagation material sold by nurseries is, in general, independent of species. The divisions (one- to two-foot culms with small portions of roots attached) sell for about 75 cents to one dollar depending on the quality of the plant.

The volume figures for domestically produced poles have been estimated from reports by producers of bamboo at about 200,000 poles per year at a value of about $30,000. When these figures are compared with the import value for this item, it is evident that the domestic production has been a small part of the total volume of bamboo poles used in this country.
2. Economic Potential

The future potential for the bamboos with established uses is expected to be about 1.3-1.5 million dollars exclusive of bags, baskets, and other imported inedible manufactured goods.

The demand for poles in this country is expected to be steady at about the 1950-51 level. If the estimated domestic value for poles is included with the import value, the 1950 figure becomes about $0.72 million and the 1951 figure $0.60 million. There are two important factors which might affect the volume demand for domestic poles. One of these is the quality of the poles offered for sale. The importers and brokers of bamboo poles maintain that domestically grown poles are inferior to imported poles; this they attribute primarily to improper curing. If better methods of curing were put into practice so that the domestic material would meet the same quality level as imported poles, it is believed that the demand would increase. The other factor is price. If domestic producers could supply poles for less than the import price, a larger market would become available in spite of the lower quality of domestic material.

Reportedly the use of split bamboo and bamboo for furniture manufacture is decreasing. Several factors, including the advent of the glass fishing rod and the use of solid rattan and other materials for furniture, have contributed to this decrease. However, it is expected that these losses will be offset by the increased uses of bamboo blinds, novelties, and decorative materials which have been brought on by the popularity of the bamboo motif in modern decorative schemes. The volume potential for split bamboo has been estimated at about one million pounds per year at six cents per pound.
The demand for bamboo bags and baskets is expected to level out at about five to six million items per year at an average price of about 11 cents per item. It seems unlikely that domestically produced raw material will find any large use in this field. The margin between gross return and labor in this country would make domestic production of bags and baskets unattractive. This seems evident when it is realized that Mexican producers with less expensive labor than that which is found in this country cannot compete economically with Oriental producers. For these reasons it is believed that the bags and baskets should be discounted as a possible outlet for domestically grown bamboo.

According to reports from importers, the consumption of edible bamboo shoots is slowly increasing in this country. The market has been estimated at two million pounds per year for about 25 cents per pound f.o.b. San Francisco. The labor required in producing this item would appear to preclude a commercial bamboo development specifically for this purpose. However, if groves of the proper species were under cultivation, this product might develop as a valuable sideline outlet.

Little change is expected in the volume demand for numerous minor uses such as sporting goods equipment and work poles. However, nurseries have reported that there is a slowly increasing demand for landscape ornamentals.

There seems to be a future potential for bamboo for some new uses in this country. Several of these, such as light structural material and as a source of cellulose fiber, are now being commercially exploited in the Orient.
To develop a commercial market for bamboo in structural uses, the proper species of bamboo, correctly cured and processed, must be available, and the general public must be informed of the usefulness of bamboo for these purposes. With wood so available in this country, it seems unlikely that this market for bamboo will develop on its own; it will probably develop as a side use of considerable volume when bamboo becomes abundantly available in various species and sizes.

Some interest has been expressed by representatives of various industrial organizations concerning the possible use of bamboo as a source of cellulosic raw materials. This interest has been based, in general, on a farsighted view of the wood pulp raw material situation, particularly in the Southeast. The overdrain on southern pine forests was reportedly about three million cords during 1950.* With the proposed expansion of the pulp industry, this would mean that about 5.5 million cords per year of southern pine will be overcut for pulpwood by 1956 if the 1951 growth rate is maintained. These conditions indicate a need for a source of cellulose fiber which will reproduce several times faster than present sources, and the bamboos have been given some consideration as a possible answer to this need. Several organizations are engaged in studies of some species of bamboo for some uses. For example, one organization is interested in using this type of material in building boards. Their experimental investigations, so far, have not reached a point which will permit them to predict the value of these materials for this purpose.

The total softboard pulpwood usage was approximately 700,000 tons in

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*Statement by Frank Heyward before the American Pulp and Paper Association meeting, New York, February 19, 1952.
1951. This represents a considerable market potential for a bamboo which could meet the requirements for this use. The price in this case would have to be competitive with pulpwood.

Several other companies have expressed interest in the bamboos as sources of fiber for roofing and building felts. This use, in general, would require a bamboo with the same characteristics as southern pine upon defibration and which sold at a cheaper price. The volume potential based on estimates from industrial organizations has been placed at about 600,000 tons per year (dry weight) of bamboo for this use.

Other uses which are possible outlets for domestically grown bamboo include a corrugated medium for containers and book and wrapping paper. Volumes for these uses have not been estimated but the price would have to be competitive with that of gum or oak at about nine dollars and fifty cents per ton (1952 price).

It should be pointed out that a pulpable bamboo which could serve as a partial replacement for Kraft pulp from southern pine could be a valuable supplement to present pine stands. If bamboo were used only to take care of the expected increased consumption of southern pine stands for pulpwood, it would have an annual volume potential equivalent to about 2.5 million cords of pine. Bamboos grown in this supplementary capacity would permit the drain and growth of pine woodlands to be brought into balance more easily. As such, the bamboos would offer assistance to the forester and would be a valuable asset to sections of the country in which they were grown.

All of these volume potentials are contingent upon finding and developing the proper bamboo for each use. The extent to which these
materials could meet the needs of the various industries as a source of raw material will depend upon both the chemical and physical characteristics of the fibers as well as upon the economics involved. There are several factors which must be considered before the bamboos can be given serious consideration by industry. These include the problems of availability, properties of the materials, and methods and economics of procurement and processing.

The problem can be summarized as one of insufficient information; therefore, industry is not at present in a position to make definite commitments about possible volume usage of the bamboos. The general feeling is that bamboo is one of several other materials which have potentialities as a cellulose fiber source, but bamboo does not possess an attractive market at present. It seems probable that these materials will come into the pulp picture in increasing amounts in the future not as dramatic replacements for wood but as gradual supplements to the available wood supply.

The volume potentials for bamboos with several uses can be summarized as follows:

1. Bamboo poles for various uses (primarily Phyllostachys aurea) should be used in the future up to a value of about $700,000 per year.

2. Split bamboo should hold steady at about one million pounds per year at about six cents per pound (a value of about $60,000).

3. Bamboo shoots should have a volume demand of about two million pounds per year at a value of about $500,000.

4. If the bamboos were used as a partial replacement for wood as a source of cellulose in the Southeast and only balanced the overdrain of
pine, a market of about 1.7 million tons of dry fiber per year would be
available.

It seems that there are market potentials for bamboo for various
uses, but before they can be developed the bamboos must be available and
the quality of the materials and the economics involved must be estab-
lished. This can be accomplished only through conclusive experimental
study. The potentials seem to be of sufficient magnitude to warrant
such experimental programs. If successful, the programs would in all
probability open up new markets with vast volume demands.

3. Bamboo as a Crop

Since the hardy species of bamboo will grow in the United States,
it would seem that domestic requirements could possibly be supplied from
plants grown in this country. However, a considerably expanded program
of production would be necessary because only a small percentage of the
bamboo used in this country is grown here.

In addition to the current demand there are fields in which it is
believed that bamboo might be utilized advantageously but in much larger
quantities than those now available. One such possibility is the use of
bamboo as a supplementary paper pulp source. The need for an additional
source of pulp is apparent when the present overcutting of wood and the
expected increased drain are considered.

It should also be noted that during World War II practically no
bamboo was imported, and the relatively small stands of domestic bamboo
were overtaxed. Some users of bamboo have been reluctant to utilize
bamboo grown in this country since they feel it is inferior to that from
the Orient. It is possible that the suppliers failed to furnish them the
species they preferred, either because the requested species were not available or because the supplier was confused as to which species he had, or the bamboo from sources in this country may sometimes have been cut immature and may not have been cured properly.

Some indication of the value of bamboo as a possible domestic crop can be obtained by considering the gross return per acre. This gross return per acre may be estimated by considering the yields which have been reported and the prices paid for various species of bamboos. Phyllostachys aurea, which is the best suited for fishing poles, has yielded by selective cutting about 1,700 canes per acre per year in this country. The price paid for these canes was eight to twelve cents each. This price is comparable to the price paid for imported poles (Table XXIII). At ten cents per cane, this would amount to $170 gross per acre. It would seem that growing bamboo for fishing poles would therefore be profitable since it is known that the planting requires very little care once it has been established. However, probably the major difficulty encountered in producing bamboo domestically for this use would be developing proper curing procedures. An experimental program would have to be established to overcome this difficulty in order to make domestic production of bamboo for fishing poles possible.

Although there is only a limited market for rug poles, the planting of species for this purpose would probably be profitable. The same bamboo, Phyllostachys bambusoides, is suitable for splitting for the manufacture of blinds, baskets, etc. This species has reportedly yielded approximately 350 canes per acre per year with selective cutting. Reports on the prices which have been paid for canes of this species have
varied from 60 cents to four dollars each. The 60-cents value was for canes 1-1/4 inches to 1-3/4 inches in diameter at the base. The prices paid for poles two inches or more in diameter varied from one to four dollars each. The present price for this size, one dollar per cane, would mean a gross return of $350 per acre. This figure would indicate that Phyllostachys bambusoides would be a very profitable crop. It should be remembered, however, that the market is limited and any large domestic production would probably result in a considerable decrease in the price.

Bamboo as a landscaping material is another potential source of income for the southern farmer. Although reports indicate that at the present time nurseries are able to supply sufficient quantities of most species for this purpose, there are some items which are not produced in large enough quantities, particularly the dwarf-type Variety disticha of Bambusa multiplex. It is not advisable to estimate the gross return per acre that could be expected from bamboo grown for sale as propagation material since in all probability such material would come from nurseries which would not grow large quantities, or from groves of bamboo grown for other purposes. If bamboo were to be considered for commercial purposes, such as for a paper pulp source, there would be a much larger demand for propagation material for specific species in order to establish sufficient growth.

There is a demand in this country for bamboo for edible shoots, furniture construction, sporting goods, novelties, and construction materials. However, it is impossible to arrive at reliable estimates for the return per acre from bamboo grown specifically for these uses. Bamboo for such
uses, with the exception of the edible shoots, could probably be supplied from bamboo grown for other purposes. Although no estimates were available on the yield of shoots that could be expected or on the value of the raw shoots, it is not likely that such a crop would be of major importance in the United States.

The fact that bamboos have been used successfully in several countries as a paper pulp source would indicate that bamboo might be an answer to the increasing need for an additional pulp source in this country. Bamboo appears to be an excellent potential crop for this purpose. Estimates of the comparative yields of cellulosic material indicate that six or seven times more raw material could be obtained per acre per year from a bamboo forest of the larger species than from a southern pine forest. The actual yield, of course, would depend upon the species of bamboo grown. This figure was calculated from an estimated yield of 1.38 tons of pine wood per acre per year from a controlled stand and from estimated yields reported for several species of bamboo (Table XIV and accompanying text).

In all probability the method of strip cutting or partial harvesting would prove to be best for this use, as it would provide for self propagation of the plants and not require the added expense and labor required by selective cutting. The details of the harvesting methods would have to be worked out to determine the optimum conditions, i.e., width of strips to be cut and frequency of cutting, chipping in the field, etc.

Frank Heyward has predicted that the paper pulp plant capacity by 1956 will require an additional 2.5 million cords of southern pine; this amount is in addition to the present overdrain from southern pine forests. If we assume that bamboo were used as a supplement to the extent of this
2.5 million cords, assume a 45 per cent recovery of pulp from air-dried bamboo, and assume that 1.5 cords of pine yield a ton of pulp, it can be shown that

\[
\frac{2.5 \text{ million cords}}{1.5 \text{ cords/ton} \times 45\% \text{ pulp from bamboo}} = 3,703,700 \text{ tons of air-dried bamboo would be required.}
\]

If an estimated yield per acre per year of 10-12 tons of dry bamboo is used, it follows that about 308 thousand to 370 thousand acres of bamboo would be necessary.

In previous discussions, the yield of pulp from bamboo was shown to be only slightly less than from pine by comparable processes. Therefore, it would be logical to assume that land devoted to growing bamboo for use as a pulp source would bring a return to the owner of approximately seven times that of land used for pulpwood production. On the basis of $13.50 per cord or $9.00 per ton for pine, and assuming that bamboo could command a comparable price, this would represent an annual gross income to the growers of approximately $90-$110 per acre of land per year.

If bamboo were also to be utilized to offset the 1951 overdrain of southern pine, using the same estimates, it can be shown that 440 thousand additional acres of bamboo would be needed. If this acreage were added to that calculated for the future expected overdrain, a total acreage of 810,000 acres will be obtained. At $100 per acre this represents a possible total gross return of $81 million.

Although no actual monetary value can be given to bamboo grown on individual farms for use around the farm, bamboo planted for this purpose would conceivably result in considerable saving to the farmer. A small grove of bamboo would require little or no care, once it had been established, and would provide the grower with raw material for the numerous
light construction frequently needed on the farm. Bamboos are particularly suited for such items as fences and plant stakes.

In addition, the consideration of utilizing these small plots of bamboo to provide nursery stock should not be overlooked. For this reason it would be worthwhile to encourage farmers to plant several species rather than just one. Specific species could also be used to provide local sources of fishing poles or other items. Small-scale growing of bamboo for fishing poles has been successful in some areas of the United States and indicates that the farmer would find bamboo an attractive crop for supplemental income.

The limited amount of available domestic bamboo has been partly responsible for the lack of interest by many United States concerns in bamboo as a raw material. It is possible that small-scale plantings may have to be established to provide adequate propagation material to make the utilization of bamboo attractive for potential large-volume uses.

F. Future Considerations for Bamboos

Markets for bamboo and bamboo products have existed in the United States for many years. The major proportion of the bamboo and bamboo products used in this country has been imported, but various species have been domestically grown successfully for commercial sale. Domestically, the major volume uses have been for poles, landscaping materials, and edible shoots. In addition, there is a demand for such manufactured items as bags, baskets, blinds, and various novelties. There is also a relatively minor demand for split bamboo, plant stakes, bamboo for ornamental construction, sporting goods, furniture, and related manufactures.
The future domestic market for bamboos for established uses is estimated to be about 1.3-1.5 million dollars, exclusive of bags, baskets, and other inedible manufactured goods.

The future demand for poles in this country is expected to go up to a value of $700,000 per year. The value of domestic production in the past has been on the order of $30,000 per year. The relationship between the amount of poles supplied from imports and that supplied domestically could be radically altered provided domestic producers could supply poles comparable in price and quality to the imported material. It would seem that growing of the species Phyllostachys aurea for use as fishing poles would be profitable since reported yields and values per pole have indicated that a gross return of $170 per acre per year could be realized, and established bamboo groves would require little care. Although there is a limited market at the present time for the larger poles from such species as Phyllostachys bambusoides, it appears that a gross return per acre from species of this size would be about $350 annually.

The demand for living bamboos for landscaping and propagation material has been slowly increasing. Nurseries which handle bamboos as stock items are able to supply sufficient quantities of desired species with the exception of some of the fern-leaf dwarf types. In the event of a large-scale commercial development requiring the cultivation of certain species of bamboo, present sources of propagation material would probably have to be supplemented.

The demand for bamboo bags and baskets is expected to be about six million items per year at an average price of eleven cents per item (import price). However, it is believed that bags and baskets will not
constitute an outlet for domestic bamboo because of the adverse economic factors involved.

The use of split bamboo and bamboo furniture is decreasing; however, it is expected that this decrease will be offset by the increasing demand for other items such as blinds, novelties, and decorative materials.

Edible bamboo shoots have been imported from China and Japan for a number of years. The market for this item in the United States is slowly increasing and has been estimated at two million pounds per year at an import price of 25 cents per pound.

Reliable estimates of the return per acre from bamboo grown for such uses as split bamboo, furniture manufacture, and edible shoots are not available, but it does not seem that bamboo could be grown profitably in the United States for these purposes.

The bamboos are now being commercially exploited for numerous applications in the Orient. Several of these, i.e., as structural materials and as a source of cellulose, have potentialities as new uses in the United States.

Certain species of bamboo have been shown to be satisfactory as concrete reinforcement. Some are ideal for lightweight construction, particularly in view of recent developments in joining devices for bamboo segments. It is not likely that bamboo will be developed for these purposes unless it becomes more common in this country and unless more widespread information becomes available concerning its properties and methods for processing and curing it.

The present supply conditions for cellulosic raw materials indicate a need for a source that could produce several times more fiber faster
than present sources. The bamboos have been given some consideration as a possible answer to this need since it has been estimated that some bamboo would produce about six or seven times more raw material per acre annually than present sources. This could conceivably result in a return per acre to the grower of approximately seven times that realized from an acre utilized for pulpwood production; however, the methods and costs for production and procurement of bamboo for cellulose in the United States have not been determined.

Considerable experimental work has been done on processing methods of bamboo for various end uses. This experimentation has indicated that, by certain processes, bamboo pulps can be produced that are satisfactory for several uses. However, the extent to which the bamboos can meet the needs of various United States industries as a source of raw material will depend upon the economics involved. Although bamboo does not possess an attractive market for these uses now, it seems probable that it will come into the pulp picture in increasing amounts in the future.

There are vast market potentials for bamboo for various uses, but the development of these markets is contingent upon several factors. Among these factors, which can only be determined through conclusive experimental studies, are the availability and quality of materials and the economics involved for each use. These potentials seem to be of a magnitude to warrant further study and, if such investigations are undertaken, they should include the following programs:
1. Plant different species of bamboo in quantities large enough to determine the best and most economical methods of production. The costs and techniques for efficient planting and harvesting should be evaluated; various ways of preparing the material for sale should be investigated.

2. Plant enough of the bamboos deemed suitable for pulp to provide an adequate supply for large-scale pulping experiments. These experiments would investigate various methods of pulping in order to establish the best and most economical ways to produce different kinds of pulp.

3. Study the physical properties of various species of bamboo, determining the optimum curing conditions and the best processing methods for each end use.

Besides this experimental work, a program for disseminating general information on bamboo growing and uses is recommended; the program encouraging farmers to plant bamboo could be expanded. Information for the general public could be released through both popular and technical media.

If these programs were successful, they could probably open vast new markets and provide southern farmers with a money-making crop beneficial to the entire country.

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VII. CONCLUSIONS AND RECOMMENDATIONS

Detailed conclusions and recommendations for the three plants studied in this phase of the program have been presented previously. However, some generalizations may be made.

The methods employed in this study are considered by be satisfactory, and it is believed that they could serve well as a guide for future investigations of this type.

Bamboos, candelilla, and Simmondsia have potential as domestic crops, but before they can be developed as major crops, some additional information concerning the economics and technology of their production and utilization must be determined. These factors should be determinable through suitable experimental programs, and the potential appears to be of sufficient magnitude to warrant such investigations.

One situation encountered in these studies was the fact that some industries which might make use of the products from the plants were unaware of these potentialities. This suggests that informational programs should be expanded. Included in this program should be the publication of the results of these studies, preferably in the form of technical bulletins, for distribution to representatives of industrial concerns and other interested organizations. It might be advisable to make part of this information available to the general public through some popular media.

Respectfully submitted:

Approved: 

H. H. Sineath P. M. Daugherty
Project Director Research Assistant

Herschel H. Cudd R. N. Hutto, III T. A. Wastler, Jr.
Acting Director Graduate Assistant Research Assistant

Engineering Experiment Station
# TABLE XXV

**ORGANIZATIONS AND INDIVIDUALS INTERESTED IN THE DEVELOPMENT OF CANDELILLA, SIMMONDSIA OR BAMBOO**

<table>
<thead>
<tr>
<th>Organization or Individual</th>
<th>Plant or Material</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best Foods, Inc. Research Laboratory</td>
<td>Simmondsia</td>
<td>Interested in the products of the plant...requested sample of the wax.</td>
</tr>
<tr>
<td>Casner Candelilla Co. Alpine, Texas</td>
<td>Candelilla Wax</td>
<td>Interested in domestic development and cultivation of candelilla.</td>
</tr>
<tr>
<td>The Champion Paper and Fiber Co. Hamilton, Ohio</td>
<td>Bamboo</td>
<td>Actively studying the bamboos for possible use in paper manufacture.</td>
</tr>
<tr>
<td>M. C. Kidder 257 S. Spring St. Los Angeles 12, Calif.</td>
<td>Bamboo Candelilla Simmondsia</td>
<td>Has formed a foundation to study chemurgic plants.</td>
</tr>
<tr>
<td>Fuld Bros., Inc. 702 South Wolfe St. Baltimore, Md.</td>
<td>Simmondsia Wax</td>
<td>Would be interested in evaluating this wax for use in polishes.</td>
</tr>
<tr>
<td>McHutchinson &amp; Co. 95 Chambers St. New York 7, N. Y.</td>
<td>Bamboo</td>
<td>Would like to use or see domestic material expanded for horticultural uses.</td>
</tr>
<tr>
<td>The Mead Corp. Chillicothe, Ohio</td>
<td>Bamboo</td>
<td>Interested in bamboo as a ---wo? inform leased on the subject.</td>
</tr>
</tbody>
</table>

*Continued*
<table>
<thead>
<tr>
<th>Organization or Individual</th>
<th>Plant or Material</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mitchell Rand Mfg. Co.</td>
<td>Simmondsia Wax</td>
<td>Would like samples of the wax for investigation...interested in development.</td>
</tr>
<tr>
<td>51 Murray St.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New York, N. Y.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. B. Weiswanger</td>
<td>Simmondsia</td>
<td>Presently working on Simmondsia as a domestic crop.</td>
</tr>
<tr>
<td>317 Clifford St.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corpus Christi, Texas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nopco Chemical Co.</td>
<td>Simmondsia Oil</td>
<td>Interested in possible use as a supplement to sperm oil...would like sample for evaluation.</td>
</tr>
<tr>
<td>Harrison Office</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harrison, N. J.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Rubberoid Co.</td>
<td>Bamboo</td>
<td>Interested in use of bamboo in roofing felts.</td>
</tr>
<tr>
<td>500 Fifth Ave.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New York 36, N. Y.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard Oil Co.</td>
<td>Candelilla Wax</td>
<td>Would like to have candelilla wax of lower tackiness.</td>
</tr>
<tr>
<td>910 South Michigan Ave.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chicago 80, Ill.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strahl and Pitsch, Inc.</td>
<td>Candelilla Wax</td>
<td>Would like to see domestic development of candelilla...would like to evaluate Simmondsia.</td>
</tr>
<tr>
<td>141 Front St.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New York 5, N. Y.</td>
<td>Simmondsia Wax</td>
<td></td>
</tr>
<tr>
<td>Dr. Ilona Taussky</td>
<td>Simmondsia Oil and Wax</td>
<td>Interested in the commercial development of Simmondsia oil and wax.</td>
</tr>
<tr>
<td>124 E. 24th St.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New York 10, N. Y.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Union Oil Co. of Calif.</td>
<td>Simmondsia Oil and Wax</td>
<td>Interested in studying the utilization of these materials in several fields.</td>
</tr>
<tr>
<td>Brea, Calif.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>University of Arizona</td>
<td>Simmondsia</td>
<td>Interested in cultivation of Simmondsia plant.</td>
</tr>
<tr>
<td>Dept. of Botany and Range Ecology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tucson, Ariz.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TABLE XXV (Continued)

ORGANIZATIONS AND INDIVIDUALS INTERESTED IN THE DEVELOPMENT OF CANDELILLA, SIMMONDSIA OR BAMBOO

<table>
<thead>
<tr>
<th>Organization or Individual</th>
<th>Plant or Material</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warick Wax Co.</td>
<td>Simmondsia Wax</td>
<td>Would like to investigate merits of this wax.</td>
</tr>
<tr>
<td>10th St. and 44th Ave.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long Island City 1, N. Y.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>West Virginia Pulp &amp; Paper Co.</td>
<td>Bamboo</td>
<td>Has experimental planting at Westvaco Exp. Forest ...interested in possible development as source of pulp.</td>
</tr>
<tr>
<td>230 Park Ave.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New York, N. Y.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dr. Llewelyn Williams</td>
<td>Candelilla</td>
<td>Interested in the domestic development of this plant.</td>
</tr>
<tr>
<td>P. O. Box 500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Plainfield, N. J.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX II

BAMBOO AS A REINFORCEMENT FOR CONCRETE

A. The Effects of Bamboo Preparation on the Bamboo-Concrete Bond

B. The Results of Tests on Bamboo-Reinforced Beams

C. Some Design and Construction Principles for Reinforcing Concrete with Bamboo

SUGGESTED PROGRAM FOR FIBER LENGTH DETERMINATIONS

STUDIES OF SULFATE PULPING PROCEDURES

A. Studies by Patettor et al.

B. Studies by Bhargava and Singh

C. Studies by Stevens

D. Studies by Tutiya and Kato

E. Studies by Arthur D. Little, Inc.

F. Studies by the Herty Foundation

SUGGESTED INVESTIGATION OF PULPING PROCEDURES

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAMBOO AS A REINFORCEMENT FOR CONCRETE</td>
<td>235</td>
</tr>
<tr>
<td>A. The Effects of Bamboo Preparation on the Bamboo-Concrete Bond</td>
<td>235</td>
</tr>
<tr>
<td>B. The Results of Tests on Bamboo-Reinforced Beams</td>
<td>238</td>
</tr>
<tr>
<td>C. Some Design and Construction Principles for Reinforcing Concrete with Bamboo</td>
<td>243</td>
</tr>
<tr>
<td>SUGGESTED PROGRAM FOR FIBER LENGTH DETERMINATIONS</td>
<td>247</td>
</tr>
<tr>
<td>STUDIES OF SULFATE PULPING PROCEDURES</td>
<td>253</td>
</tr>
<tr>
<td>A. Studies by Patettor et al.</td>
<td>253</td>
</tr>
<tr>
<td>B. Studies by Bhargava and Singh</td>
<td>254</td>
</tr>
<tr>
<td>C. Studies by Stevens</td>
<td>255</td>
</tr>
<tr>
<td>D. Studies by Tutiya and Kato</td>
<td>255</td>
</tr>
<tr>
<td>E. Studies by Arthur D. Little, Inc.</td>
<td>256</td>
</tr>
<tr>
<td>F. Studies by the Herty Foundation</td>
<td>256</td>
</tr>
<tr>
<td>SUGGESTED INVESTIGATION OF PULPING PROCEDURES</td>
<td>269</td>
</tr>
</tbody>
</table>
### TABLE XXVI-A

CHEMICAL CONSTITUENTS OF BAMBOOS

<table>
<thead>
<tr>
<th>Chemical Constituents of Shoots and Sheaths of Madake (Phyllostachys bambusoides)</th>
<th>Internode (Per Cent)</th>
<th>Node (Per Cent)</th>
<th>Young Sheath (Per Cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>93.0</td>
<td>93.0</td>
<td>81.3</td>
</tr>
<tr>
<td>Residue</td>
<td>7.0</td>
<td>7.0</td>
<td>18.7</td>
</tr>
<tr>
<td>Ash</td>
<td>9.9</td>
<td>11.8</td>
<td>--</td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>4.9</td>
<td>3.3</td>
<td>1.8</td>
</tr>
<tr>
<td>Soluble Nitrogen</td>
<td>50.2</td>
<td>45.0</td>
<td>41.0</td>
</tr>
<tr>
<td>Alcohol-Soluble Nitrogen</td>
<td>3.0</td>
<td>1.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Protein Nitrogen</td>
<td>38.0</td>
<td>42.0</td>
<td>57.0</td>
</tr>
<tr>
<td>Total Reducing Sugar</td>
<td>15.7</td>
<td>12.6</td>
<td>11.6</td>
</tr>
<tr>
<td>Pentoses</td>
<td>7.0</td>
<td>12.0</td>
<td>9.0</td>
</tr>
<tr>
<td>Hexoses</td>
<td>93.0</td>
<td>85.0</td>
<td>91.0</td>
</tr>
<tr>
<td>Remainder</td>
<td>34.4</td>
<td>43.0</td>
<td>77.6</td>
</tr>
<tr>
<td>Pentosans</td>
<td>12.4</td>
<td>23.7</td>
<td>28.8</td>
</tr>
<tr>
<td>Lignin</td>
<td>5.3</td>
<td>0.7</td>
<td>14.8</td>
</tr>
<tr>
<td>Cellulose</td>
<td>16.7</td>
<td>18.6</td>
<td>34.0</td>
</tr>
</tbody>
</table>

*Reference: 132—as reported in 243.*
TABLE XXVI-B
CHEMICAL CONSTITUENTS OF BAMBOOS

<table>
<thead>
<tr>
<th>Chemical Constituents of Culm Sheaths at Different Ages of Madake (Phyllostachys bambusoides)</th>
<th>Young (Per Cent)</th>
<th>Medium (Per Cent)</th>
<th>Old (Per Cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>90.0</td>
<td>84.0</td>
<td>62.0</td>
</tr>
<tr>
<td>Residue</td>
<td>10.0</td>
<td>16.0</td>
<td>38.0</td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>3.3</td>
<td>1.9</td>
<td>1.0</td>
</tr>
<tr>
<td>Soluble Matter</td>
<td>34.0</td>
<td>20.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Total Reducing Sugar</td>
<td>19.0</td>
<td>12.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Pentosans</td>
<td>22.0</td>
<td>28.0</td>
<td>33.0</td>
</tr>
<tr>
<td>Lignin</td>
<td>11.0</td>
<td>18.0</td>
<td>20.0</td>
</tr>
<tr>
<td>Cellulose</td>
<td>23.0</td>
<td>37.0</td>
<td>43.0</td>
</tr>
</tbody>
</table>

*Reference: 132—as reported in 243.

TABLE XXVI-C
CHEMICAL CONSTITUENTS OF BAMBOOS

<table>
<thead>
<tr>
<th>Chemical Constituents of Nodal Region of a Bamboo Culm</th>
<th>Nodes of Young Culm at Different Positions From Base to Tip</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
</tr>
<tr>
<td></td>
<td>(Per Cent)</td>
</tr>
<tr>
<td>Water</td>
<td>90.5</td>
</tr>
<tr>
<td>Residue</td>
<td>9.5</td>
</tr>
<tr>
<td>Ash</td>
<td>8.8</td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>2.8</td>
</tr>
<tr>
<td>Total Reducing Sugar</td>
<td>13.7</td>
</tr>
<tr>
<td>Ether Extract(Paw, etc.)</td>
<td>6.4</td>
</tr>
<tr>
<td>Cellulose</td>
<td>24.3</td>
</tr>
<tr>
<td>Lignin</td>
<td>1.0</td>
</tr>
<tr>
<td>Pentosans</td>
<td>32.0</td>
</tr>
</tbody>
</table>

*Reference: 132—as reported in 243.
Phase Report No. 3, Project No. 177-170

TABLE XXVI-D

CHEMICAL CONSTITUENTS OF BAMBOOS*

<table>
<thead>
<tr>
<th>Chemical Constituents of the Internodes of a Bamboo Culm</th>
<th>Internodes of Young Culm at Different Positions From Base to Tip (Per Cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
</tr>
<tr>
<td>Water</td>
<td>91.9</td>
</tr>
<tr>
<td>Residue</td>
<td>8.1</td>
</tr>
<tr>
<td>Ash</td>
<td>7.3</td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>2.7</td>
</tr>
<tr>
<td>Total Soluble Matter</td>
<td>39.9</td>
</tr>
<tr>
<td>Fat</td>
<td>3.6</td>
</tr>
<tr>
<td>Total Reducing Sugar</td>
<td>16.7</td>
</tr>
<tr>
<td>Pentoses</td>
<td>0.9</td>
</tr>
<tr>
<td>Pentosans</td>
<td>5.3</td>
</tr>
<tr>
<td>Cellulose</td>
<td>29.6</td>
</tr>
</tbody>
</table>

* Reference: 132—as reported in 243.

TABLE XXVI-E

CHEMICAL CONSTITUENTS OF BAMBOOS*

<table>
<thead>
<tr>
<th>Chemical Constituents from Outer to Inner Parts of a Bamboo Culm</th>
<th>Culm Wall from Outermost to Innermost Part (Per Cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( A_1 ) (Per Cent) ( A_2 ) (Per Cent) ( A_3 ) (Per Cent) ( A_4 ) (Per Cent)</td>
</tr>
<tr>
<td>Water</td>
<td>90.0</td>
</tr>
<tr>
<td>Residue</td>
<td>10.0</td>
</tr>
<tr>
<td>Ash</td>
<td>18.0</td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>3.6</td>
</tr>
<tr>
<td>Ether Extract</td>
<td>16.8</td>
</tr>
<tr>
<td>Total Reducing Sugar</td>
<td>18.0</td>
</tr>
<tr>
<td>Cellulose</td>
<td>20.0</td>
</tr>
<tr>
<td>Pentosans</td>
<td>14.0</td>
</tr>
</tbody>
</table>

* Reference: 132—as reported in 243.
### TABLE XXVI-F

**CHEMICAL CONSTITUENTS OF BAMBOOS***

<table>
<thead>
<tr>
<th>Chemical Constituents of a Bamboo Culm During the Period from Shoot Stage to Adult Stage</th>
<th>Composition (Per Cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>90.0</td>
</tr>
<tr>
<td>Residue</td>
<td>10.0</td>
</tr>
<tr>
<td>Ash</td>
<td>2.5</td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>2.0</td>
</tr>
<tr>
<td>Fats</td>
<td>5.4</td>
</tr>
<tr>
<td>Total Reducing Sugar</td>
<td>3.5</td>
</tr>
<tr>
<td>Pentosans</td>
<td>32.0</td>
</tr>
<tr>
<td>Cellulose</td>
<td>47.0</td>
</tr>
<tr>
<td>Lignin</td>
<td>0.6</td>
</tr>
</tbody>
</table>

*Reference: 132—as reported in 243.

### TABLE XXVI-G

**CHEMICAL CONSTITUENTS OF BAMBOOS***

<table>
<thead>
<tr>
<th>Chemical Constituents of the Culm of Mosochiku (Phyllostachys edulis)</th>
<th>Composition After Removal of Water (Per Cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Protein</td>
</tr>
<tr>
<td></td>
<td>Fats</td>
</tr>
<tr>
<td></td>
<td>Fiber</td>
</tr>
<tr>
<td></td>
<td>Starch</td>
</tr>
<tr>
<td></td>
<td>d-Glucose</td>
</tr>
<tr>
<td></td>
<td>Soluble Non-nitrogenous Substances</td>
</tr>
<tr>
<td></td>
<td>Ash</td>
</tr>
<tr>
<td></td>
<td>Other Constituents</td>
</tr>
<tr>
<td>Total</td>
<td>100.00</td>
</tr>
</tbody>
</table>

*Reference: 132—as reported in 243.
BAMBOO AS A REINFORCEMENT FOR CONCRETE

A. The Effects of Bamboo Preparation on the Bamboo-Concrete Bond

The various curing treatments for culms used in this study of the bamboo-concrete bond are listed in Table XXVII. Several observations on requirements for a good bond have been made from a study of this table.

1. The specimens used for series nine and ten were prepared using green (unseasoned), whole culms and were cured in water for a period of one week. They were then removed from the water and allowed to room-dry for 144 days. At the end of the drying period the culms had shrunk so much that the ability to bond the bamboo to the concrete was completely destroyed or seriously impaired.

2. Load-carrying members of bamboo-reinforced concrete are very likely to develop cracks when green culms are used because the bond between the concrete and bamboo deteriorates if the encased culms dry out.

3. Even though bond slippage is almost certain to occur when green culms are used, some degree of bond is caused by the protrusion at the nodes and by the wedging action of the culm taper (from the basal to the distal end).

4. As shown by series five, seasoned culms develop much higher bond values than do green culms. Individual tests show that bond values of seasoned culms vary greatly from specimen to specimen. Bond values appear to vary with the degree that the seasoned culm swells by absorbing moisture from the concrete mixing water and subsequently shrinks when the moisture leaves the bamboo after the concrete hardens. The swelling of the unseasoned culms in many cases causes the concrete in a bamboo-reinforced concrete member to crack along the longitudinal axis of the
### TABLE XXVII

**BOND BETWEEN BAMBOO AND PORTLAND CEMENT CONCRETE (106)**

<table>
<thead>
<tr>
<th>Series No.</th>
<th>No. of Tests</th>
<th>Method of Curing</th>
<th>Loading Condition</th>
<th>Unit Bond Stress</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Slip (psi)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Failure (psi)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th>at First</th>
<th>at Slip</th>
<th>at Failure</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
<td>21 days in water (1)</td>
<td>---</td>
<td>88</td>
<td>Green culms without nodes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>8</td>
<td>21 days in water (2)</td>
<td>---</td>
<td>134</td>
<td>Same as above</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>21 days in water (1)</td>
<td>---</td>
<td>43</td>
<td>Same as above</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>Same as above (2)</td>
<td>---</td>
<td>74</td>
<td>Same as above</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>Same as above (1)</td>
<td>40</td>
<td>84</td>
<td>Same as above</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>Same as above (2)</td>
<td>48</td>
<td>118</td>
<td>Same as above</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>21 days in water (1)</td>
<td>83</td>
<td>127</td>
<td>Same as above</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>21 days in water (2)</td>
<td>92</td>
<td>188</td>
<td>Same as above</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>21 days in water (1)</td>
<td>---</td>
<td>78</td>
<td>Well-seasoned culms without nodes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>Same as above (2)</td>
<td>---</td>
<td>122</td>
<td>Same as above</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>8</td>
<td>Same as above (1)</td>
<td>---</td>
<td>55&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Well-seasoned culms, asphalt emulsion brush coat, without nodes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>12</td>
<td>Same as above (2)</td>
<td>---</td>
<td>99&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Same as above</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7&lt;sup&gt;c&lt;/sup&gt;</td>
<td>6</td>
<td>Same as above (1)</td>
<td>240</td>
<td>350</td>
<td>Well-seasoned culms, asphalt emulsion brush coat, with nodes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Continued)
TABLE XXVII (Continued)
BOND BETWEEN BAMBOO AND PORTLAND CEMENT CONCRETE (106)

<table>
<thead>
<tr>
<th>Series</th>
<th>No. of Tests</th>
<th>Method of Curing</th>
<th>Loading Condition</th>
<th>Unit Bond Stress</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>20</td>
<td>7 days in water 148 days' room drying</td>
<td>(1)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>20</td>
<td>Same as above</td>
<td>(2)</td>
<td>---</td>
<td>7.2</td>
</tr>
<tr>
<td>10</td>
<td>12</td>
<td>Same as above</td>
<td>(1)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>12</td>
<td>Same as above</td>
<td>(2)</td>
<td>0</td>
<td>9.2</td>
</tr>
</tbody>
</table>

(1) Basal end is down; load is applied to distal end.
(2) Distal end is down; load is applied to basal end.

a In this series, the high value was 99 psi; the low value was 7.8 psi.
b In this series, the high value was 150 psi; the low value was 22 psi.
c With the distal end down and the load applied to the basal end, the bamboo failed in compression before bond failure occurred.
d In this series, the high value was 13.2 psi; the low value was 0 psi.
e In this series, the high value was 16.2 psi; the low value was 0 psi.

RESULTS OF BOND TESTS

The ultimate bond stress between concrete and bamboo (chiefly Arundinaria gigantea) ranged from a high of approximately 350 psi to a low of zero psi. As the concrete used in all the tests was of the same grade, the only possible variable that could explain the diversity of the results was the bamboo. Bamboo has a relatively high shrinkage factor from the green to the seasoned stage. This shrinkage is much greater across the diameter than along the culm length. Several factors influence the degree of shrinkage to be expected when a freshly cut culm is seasoned. Among these factors is the age of the culm and the season of the year in which it is cut. Many old culms standing in a bamboo grove have undergone considerable seasoning, which is indicated by the brown color of the stalk.
reinforcing culms. The use of high-early-strength cement seems to have some merit in preventing swell cracks in the concrete. This is attributed to the early development of strength sufficient to resist the swelling action of the bamboo culm.

5. Seasoned, treated culms develop higher bond values over a period of time than do green or seasoned-but-untreated culms. Asphalt emulsion is a good waterproofing agent for seasoned culms and, therefore, lessens the swelling action caused by absorbed moisture. When an excess of any asphalt-based waterproofing agent is used, the lubricating effect of the excess asphalt on the surface of the culm is likely to lessen the bond value.

6. The behavior of test beams made in the laboratory and of load-carrying members constructed in the field seems to verify the conclusions reached in this series of bond tests.

7. When green, whole culms are used in bamboo-reinforced concrete members, the bond value will depend entirely on the protrusions at the nodal regions, the taper and the irregularities of the culm. This bond value will vary greatly because all culms differ in these characteristics. Also, load-carrying members of concrete reinforced with green culms are almost sure to develop cracks in the concrete before the bond can develop.

B. The Results of Tests on Bamboo-Reinforced Beams (106)

1. Bamboo (Arundinaria gigantea, A. tecta and Phyllostachys bambusoides) reinforcement in concrete beams does not prevent cracking at loads very much greater than those at which cracking is expected in unreinforced concrete of the same dimensions.
2. Bamboo reinforcement of a concrete beam increases the load capacity at ultimate failure considerably above that of an unreinforced member with the same dimensions.

3. The load capacity of bamboo-reinforced concrete beams increases with increasing percentages of reinforcement up to an optimum value.

4. The optimum value occurs when the cross-sectional area of the longitudinal reinforcement is from three to four per cent of the cross-sectional area of the concrete beam.

5. The load required for the failure of concrete beams reinforced with bamboo is from four to five times greater than the failure load for concrete members with the same dimensions and no reinforcement.

6. Concrete beams with longitudinal bamboo reinforcement may be designed to carry safely loads from two to three times greater than the loads carried by unreinforced concrete members having the same dimensions.

7. Concrete beams reinforced with unseasoned bamboo show slightly greater load capacities than do similar members reinforced with seasoned-but-untreated bamboo. This statement is valid only if the unseasoned bamboo has not dried out and seasoned in the concrete before the load is applied.

8. When unseasoned, untreated bamboo is used as longitudinal reinforcement, the dry bamboo swells as it absorbs moisture from the wet concrete. This swelling action often causes longitudinal cracks, reducing the load capacity of the concrete member. These swell cracks are more likely to occur in members where the percentage of bamboo reinforcement is high. This tendency to crack is lessened when high-early-strength concrete is used.
9. The unit stress in longitudinal reinforcing bamboo in concrete members decreases with increasing percentages of reinforcement.

10. The ultimate tensile strength of the bamboo in bamboo-reinforced concrete members is not affected by changes in the cross-sectional area of the members so long as the ratio of breadth to depth is constant, but it is dependent upon the amount of bamboo used for reinforcement.

11. Members having the optimum percentage of bamboo reinforcement (between three and four per cent) are capable of producing longitudinal stresses in the bamboo of from 8,000 to 10,000 pounds per square inch.

12. In designing concrete members reinforced with bamboo, a safe longitudinal stress for the bamboo of from 5,000 to 6,000 psi may be used.

13. Concrete members reinforced with seasoned bamboo which has been treated with a brush coat of asphalt emulsion develop greater load capacities than do similar members in which the bamboo reinforcement is seasoned-but-untreated or unseasoned.

14. When seasoned bamboo treated with a brush coat of asphalt emulsion is used as the longitudinal reinforcement for concrete members, there is some tendency for the concrete to develop swell cracks, especially if the percentage of bamboo reinforcement is high.

15. Care should be exercised when using asphalt emulsion as a waterproofing agent on seasoned bamboo since an excess of the emulsion on the surface of the culm may act as a lubricant, considerably lessening the bond between the concrete and bamboo.

16. Concrete members reinforced with unseasoned sections of culms which have been split along their horizontal axes appear to develop
greater load capacities than do similar members in which the reinforcement is unseasoned whole culms.

17. Concrete members reinforced with seasoned sections of bamboo culms which have been split along their horizontal axes and treated with a brush coat of asphalt emulsion develop considerably higher load capacities than do similar members in which the reinforcement is of split sections of seasoned-but-untreated bamboo.

18. When split sections of seasoned-but-untreated, large-diameter culms are used to reinforce a concrete beam, longitudinal cracks appear in the concrete as a result of the swelling action of the bamboo. This cracking is sufficient to virtually destroy the load capacity of the member.

19. When unseasoned bamboo is used to reinforce a concrete member, the bamboo encased in the concrete seasons and shrinks over a period of time. This seasoning action of the bamboo greatly reduces the effective bond between the bamboo and concrete with a resultant decrease in the load capacity of the member.

20. Increasing the strength of the concrete used increases the load capacity of a bamboo-reinforced concrete member.

21. Concrete members reinforced with seasoned bamboo treated with methylolurea do not develop greater load capacities than do similar members reinforced with seasoned culms treated with a brush coat of asphalt emulsion.

22. The load capacities for concrete members reinforced with unseasoned, seasoned, or seasoned and treated bamboo culms are increased by using split bamboo dowels as the diagonal tension reinforcement along the sections of the beams where vertical shear is high.
23. The load capacities for concrete members reinforced with unseasoned, seasoned, or seasoned and treated split sections of bamboo are increased both by using the split dowels and by bending up the upper rows of the split bamboo from the bottom of the beam into the top to cover the sections of the beam where the vertical shear is high.

24. The ultimate failure of bamboo-reinforced concrete members is usually caused by diagonal tension failures, even when diagonal tension reinforcement is provided.

25. A study of the deflection data for all the beam specimens tested indicates:

(a) That the deflections of the beams, when tested, follow a fairly accurate straight-line relation until the appearance of the first crack in the concrete;

(b) That immediately following the appearance of this first crack there is a pronounced flattening of the deflection curve (probably because of local bond slippage), followed by another period of fairly accurate straight-line relation, but at a lesser slope, until ultimate failure of the member occurs. This flattening of the deflection curve is more pronounced in members where the amount of longitudinal bamboo reinforcement is small; and

(c) That in all cases noted, the deflection curve has a lesser slope after the appearance of the first crack in the concrete, even though high percentages of bamboo reinforcement are used.

26. In order to compare bamboo-reinforced concrete members with T-shaped and rectangular cross sections, the breadth of the "stem" of the T-section must be equal to the breadth of the rectangular section, and
the effective depth of both must be the same. Under these conditions, T-shaped members under flexure are no more effective than the rectangular beam.

27. No pronounced variations are observed for reinforced concrete members when the behavior of T-shaped and rectangular members is compared under flexure.

C. Some Design and Construction Principles for Reinforcing Concrete with Bamboo (106)

1. In important concrete members whole culms of unseasoned bamboo (Arundinaria gigantea, A. tecta, and Phyllostachys bambusoides) are not recommended for use as reinforcing material. In concrete slabs and secondary members, unseasoned whole culms may be successfully used if the culm diameter does not exceed 3/4 inch. When possible, the bamboo for reinforcing concrete members subject to flexure should be cut and seasoned for three weeks to one month.

2. Bamboo culms cut in the spring or early summer season are not recommended for concrete members subject to flexure. Only those culms of a pronounced brown color should be selected from a native bamboo grove. This practice will ensure that the culms selected are at least three years old.

3. When thoroughly seasoned whole bamboo culms are used to reinforce important concrete members subject to flexure, some type of waterproofing is recommended.

4. When seasoned split bamboo from large-diameter culms is used as the reinforcing material in concrete members under flexure, some type of waterproof coating is recommended in all important load-carrying members.
However, for slabs and secondary members and for concrete sections large enough to place the bamboo splints at least 1-1/2 to 2 inches apart, unseasoned bamboo sections are recommended provided that high-early-strength cement is also used. These split bamboo splints should never have a width greater than 3/4 inch.

5. Split bamboo culms placed perpendicular to the longitudinal bamboo reinforcement are recommended to provide for diagonal tension stresses in members under flexure at the places where the vertical shear is high and where it is impractical to bend up the longitudinal bamboo. In continuous members, when conditions permit, the practice of bending up the main longitudinal bamboo reinforcement at points of heavy shear to provide for diagonal tension stresses is recommended. Also, whenever it is practical, a combination of both methods is suggested.

6. The proper spacing of bamboo reinforcement is very important. Tests indicate that, when the main longitudinal bamboo reinforcement is spaced too closely, the flexural strength of the member is adversely affected. Also, when the main longitudinal bamboo reinforcement is used in vertical rows, and when the top row is near the neutral axis of the member, the area of concrete at this section may be reduced enough to cause failure of the member under horizontal shear. In many of the specimens tested under flexural loads, the cause of failure was attributed to horizontal shear; however, in most instances of this failure horizontal cracks existed in the concrete from the swelling action of the bamboo reinforcement.

7. In placing the bamboo reinforcement care should be taken to alternate the basal and distal ends of the culms. This practice will ensure
a fairly uniform reinforcement throughout the length of the member; the resultant wedging effect will greatly increase the bond value.

8. The design of structural members for flexural loads will be governed by the specified amount of deflection. In all concrete members a high degree of deflection is obtained before failure occurs; therefore, failures from other causes usually occur considerably before the bamboo reinforcement reaches its ultimate tensile strength. Tensile stresses below 3,000 to 4,000 pounds per square inch are usually required if the deflection of the member is to be less than 1/360 of the span length. When this stress design value is kept low, a high safety factor against ultimate failure of the member usually results.

9. The same procedure as that used to design structural concrete reinforced with steel is recommended for the design of concrete members reinforced with bamboo. Values have been recommended for the maximum unit bond stress between concrete and bamboo, for the maximum unit tensile stress in the longitudinal bamboo reinforcement and for the modulus of elasticity for bamboo (2,000,000 to 3,000,000 psi). These recommended values should be used in designing a concrete member for flexural loading. It is also recommended that T-beams be designed as rectangular beams ignoring the flange width in the calculations.

10. More extensive future research should include some important points concerning characteristics of bamboo-reinforced members:

(a) The use of those species of bamboo in which the modulus of elasticity is higher than that of the species used in these experiments,

(b) More exact data on diagonal tension reinforcement,
(c) Further tests of the use of green bamboo culms for reinforcement when the bamboo will be completely seasoned after having been set in concrete,

(d) More exact data on the bond between concrete and bamboo,

(e) The use of waterproofing agents other than those used in these tests to prevent the swelling of seasoned bamboo in wet concrete.
SUGGESTED PROGRAM FOR FIBER LENGTH DETERMINATIONS

In view of the fact that data on the average fiber length of various species of bamboos reported by investigators in this country vary considerably from those reported by Formosan and Japanese sources, it is desirable that a program be initiated to ascertain these fiber lengths in a fully reliable manner. Investigation has disclosed the possibility of errors in authentication of bamboo material, method of sampling, method of maceration, and method of fiber count. Consequently, the results which have been presented to date on fiber lengths of the various bamboos must necessarily be considered inconclusive, and controlled tests should be made in order to obtain dependable information. This information would be a valuable aid in determining the future industrial potential for bamboo pulps, since it would assist us in our discussions with representatives of organizations interested in bamboo. It would also assist us in selecting the special paper field which should be investigated with reference to certain species of bamboo.

With this in mind the following outline is suggested as a guide in making fiber length determinations:

A. Authentication of species of bamboo and sampling procedure.

1. The material should be authentic as to species. It is felt that if any doubt exists as to the definite identification of any sample it should not be included in the investigation.

2. The location of growth, age, dimension of culms, and time since cutting should be established.
3. Representative culms of the same age and species should be taken for each determination. Samples of several ages should be included if possible. Ages from one to five years should be sufficient.

4. The culms selected as representative of the species (about five in number) should be uniformly sampled from top to bottom. A strip approximately one-eighth of an inch wide cut through the culm wall over the entire length of each culm should be taken. Each of these strips would then be cut into one-inch lengths, uniformly mixed and eight pieces taken at random from each sample. The resulting 40 pieces should be macerated for the fiber measurement.

B. Method of maceration and preparation of sample.

Some modification of the following basic procedure should be used.

For a sample of 10-20 grams use:

- 2.5 grams of potassium chlorate
- 50 cc of water
- 150 cc of concentrated nitric acid (Note 1).

1. Weigh a representative sample of material and boil it in water until it is saturated or until all the air is expelled.

2. Place the required amount of potassium chlorate in a flask of sufficient volume and add the water, the sample, and the nitric acid, in that order.

3. Let stand at some specific temperature (Note 2) until the fibers of the sample can be easily separated by pressing it against the wall of the tube with a glass stirring rod. Fiber separation may be effected by shaking until a uniform suspension is obtained.
4. The fibrous material is then separated from the solution and washed well with water (Note 3).

5. The washed fiber is suspended by shaking it in enough water to give a uniform suspension.


NOTES

1. Potassium chlorate--nitric acid mixtures can be dangerous so a face shield is recommended.

2. Room temperature is the most convenient although higher temperatures should give faster maceration.

3. A centrifuge serves well for this purpose. Washings should be continued until the wash water is no longer acidic.

It is suggested that this procedure be modified to give the best separation of the fibers with the least damage to them. It is suggested, therefore, that some preliminary tests be made on a uniform sample of material to determine the effects of the concentrations of reagents and length of digestion time. Our belief is that the maceration procedure for bamboo could be much milder than for wood.

The following procedure is suggested as a guide (this is based on the stated concentrations of chemicals with the time of digestion varied):

To obtain uniform samples of some species of bamboo, a section cut from one midculm internode about four inches long and split into
slivers about one-eighth of an inch thick should suffice. (Probably exclude the flat section of the internode.) Each of these slivers can then be cut into three or four equal lengths to be digested. At least three samples should be digested for each specific time interval, preferably cut from the same four-inch length. Intervals of time ranging from one hour to about 10 hours should be checked, with an added check at longer time intervals, such as 12, 15, and 24 hours. Each of these samples should be examined to determine the fiber lengths.

By this and by varying the concentration of the chemicals, the proper procedure could be determined. (It may be that with the stated concentration of potassium chlorate the bamboo fibers will be damaged.)

C. Procedure for fiber count.

1. The simplest, although probably not the most practical, method would be to measure the fibers with the aid of a microscope. The actual count should include at least 200 fibers and the actual length for each fiber recorded for averaging.

2. An alternative method would be to make photomicrographs, making sure that at least 200 fibers are within the view, and measure the fibers from these pictures.

3. A second alternative would be to prepare a slide by sandwiching the fiber suspension between two microscope slides and securing them together. This slide could then be projected upon a screen and this expanded view could be used to measure the lengths.

The second procedure has the advantage of providing a permanent record and would probably prove more convenient. The last procedure would probably prove to be the most accurate and if the slides were
handled carefully, they could serve as a semipermanent record. A preliminary examination has shown congo red dye to impart a definite color to the fibers for greater contrast. (The washed fibers were boiled for a few minutes with an aqueous solution of the dye and the excess removed by washing with water. A few drops of hydrochloric acid will change the red-dyed fiber to a dark blue if this color is preferred.)

It is believed that proper pursuance of the procedures described above will produce sufficiently reliable measurements of the fibers from various species of bamboo. It may also indicate something about the actual pulping processes that should be used for various bamboos. Because of this possibility it is suggested that the remainder of the sample pieces of material be retained and appropriately labeled as to species, age, etc., for possible future laboratory pulping tests. It would be desirable to use (for these tests, if they are made) the identical samples for which fiber lengths were determined, in order to determine the effect of pulping on the fibers.
STUDIES OF SULFATE PULPING PROCEDURES

A. Studies by Patettor et al. (183)

A study of the sulfate pulping of Guadua paraguayana under varying conditions showed the following results:

The pulp yield decreased with increased cooking temperature and increased active alkali. The maximum yield was 54.2 per cent, obtained with a cooking temperature of 130° C and 14 per cent (expressed as NaOH) active alkali, while the minimum was 40.5 per cent, cooked at 165° C with 20 per cent active alkali. The permanganate index was generally found to increase with increased cooking temperature and to decrease with increased active alkali, although this trend was not so well-defined as that of the pulp yield. The maximum permanganate number, obtained by cooking at 165° C with 14 per cent active alkali, was 48.6, while the minimum number, 12.0, was obtained by cooking at 165° C with 23 per cent active alkali. In all the above-mentioned cases, the following variables (those other than cooking temperature and per cent active alkali) were held constant: moisture content of chips, 11 per cent; sulfide content of solution, 23 per cent; ratio of dry cane to solution, 1:3.8; time in reaching maximum temperature, 1-1/4 hours; time at maximum temperature, 5-1/2 hours. Plots of the results obtained from these cooks showed, for example, that to obtain a raw or semi-cooked pulp with a permanganate index between 20 and 35 with a pulp yield between 49 and 54 per cent, the active alkali necessary fluctuates between 14 and 17 per cent, and the optimum cooking temperature is approximately 130° C. If an easily bleached pulp with a permanganate
index between 10 and 20 and a pulp yield of 43 to 48 per cent is desired, the active alkali necessary fluctuates between 17 and 23 per cent of the dry wood, and the optimum temperature is approximately 150° C. These figures were based on the cooking times and liquor concentrations described above. In the range of 18 to 20 per cent active alkali, the mechanical properties of the bleached pulps became poorer as the cooking temperature was increased. The tests on the mechanical properties of pulps from the cooks described above were preceded by a procedure in which the bleached pulps were beaten in a Lampen mill, and the indices were brought to a fixed fat content figure (45° Schopper Riegler). Tests of tensile breaking strength, bursting strength, tearing strength, and double folding strength were conducted.

<table>
<thead>
<tr>
<th></th>
<th>Tensile</th>
<th>Bursting, kg/cm²</th>
<th>Tearing</th>
<th>Double Folding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unbleached pulps</td>
<td>8,100</td>
<td>5,200</td>
<td>3.5</td>
<td>2.3</td>
</tr>
<tr>
<td>Bleached pulps</td>
<td>8,000</td>
<td>3,400</td>
<td>3.5</td>
<td>1.3</td>
</tr>
</tbody>
</table>

B. Studies by Bhargava and Singh (74)

Chips (0.5-1 in.) of air-dried *Dendrocalamus longispatus* were digested with a solution containing two parts NaOH and one part Na₂S made up to the equivalent of 32 g/1 as NaOH. Eighty-eight parts of bamboo were used per 12 parts of solution. The mixture was cooked for four hours at 40 psi (reckoned from the time of obtaining 100° C.) and yielded 62 per cent brown Kraft pulp on an air-dry basis. Strength evaluations by the Paper Makers' Association method showed that, after beating to about 400° (Canadian standard freeness tester), the values compared favorably with, although they were less than, those of normal Swedish Kraft wood
pulps. The bamboo pulp was more easily hydrated than Swedish Kraft wood pulp, but beating to less than 400° Canadian standard freeness did not appreciably increase the strength, although an increase of pressure (from 50 to 100 psi) while forming the sheets raised the bursting and tensile strengths.

C. Studies by Stevens (238)

Observations made on an undesignated species of bamboo pulped by the sulfate process showed that it produced a fiber of the highest quality; the fiber length was only a trifle shorter than that from sulfate pulp. By using 20 per cent NaOH and seven per cent Na₂S and by cooking for six hours at a pressure of 90 pounds with eight pounds of liquor to one pound of bamboo, unbleached and bleached yields of 50 per cent and 44 per cent, respectively, were obtained. The bleached bamboo pulp was particularly adapted for the manufacture of book papers requiring a soft well-closed sheet which is extremely opaque and which bulks well with a high finish.

D. Studies by Tutiya and Kato (261)

These experimenters found that Na₂S was more effective than NaOH for pulping three-year-old "Keitiku"; the optimum ratio of Na₂S to NaOH was 0.6. The yield of pulp, bleached by chlorine, was about 32 per cent and was less than that obtained by the magnesium sulfite method. The unbleached pulp contained 2.9 per cent lignin and was easily bleached by chlorine, caustic, or bleaching powder. The copper index and relative viscosity showed that there was only a slight destruction of cellulose. The bleached pulp contained 90 per cent α-cellulose, but it was unsuitable for the preparation of rayon because of its high pentosan content.
E. Studies by Arthur D. Little, Inc. (144)

In an investigation carried out in 1920 for the Bureau of Plant Industry, USDA, Arthur D. Little, Inc., (144) reported the following results obtained from pulping *Phyllostachys bambusoides*: caustic, 20 per cent (all percentages are based on the bone-dry weight of bamboo); Na₂S, seven per cent; liquor ratio, five pounds of liquor per pound of bamboo; the time for the cook, seven hours at 90 psi; the unbleached yield, 35 per cent; the bleached yield, 33 per cent; the bleach consumption, 6-1/2 per cent. The company felt that these results were not representative of the cooking conditions best suited to *Phyllostachys bambusoides*; these could be determined by more elaborate investigation. It also concluded that the yield of bleached pulp could be materially increased.

F. Studies by the Herty Foundation (52, 54)

The Herty Foundation at Savannah, Georgia, has conducted several series of pulping investigations using *Phyllostachys bambusoides* obtained from the United States Barbour Lathrop Plant Introduction Garden near Savannah. Results and conditions for one series (54) are shown in Table XXVIII.

Pulp from Cook No. 1 consumed 15.0 per cent of 35 per cent bleach to attain a brightness of 75 (G.E.), while the No. 2 pulp bleached to 81.9 brightness, consuming 22.2 per cent bleach on the same basis.

Results of the Mullen test on unbleached paper ranged from 161 to 186 maximum, and the corresponding tear ranged from 515 to 382. The softer pulp (Cook No. 1) gave the best Mullen and the lower tear results.

The bleached pulps gave Mullen results of 128 to 160 and tears of 272 and 326. The softer pulp gave the best Mullen and also the best
<table>
<thead>
<tr>
<th>Conditions and Results</th>
<th>Cook Number One</th>
<th>Cook Number Two</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total alkali (gm/1 Na₂CO₃)</td>
<td>165</td>
<td>160</td>
</tr>
<tr>
<td>Active alkali (gm/1 Na₂CO₃)</td>
<td>148.5</td>
<td>144</td>
</tr>
<tr>
<td>Per cent causticity (gm/1 Na₂CO₃)</td>
<td>63.3</td>
<td>65</td>
</tr>
<tr>
<td>Per cent sulfidity (gm/1 Na₂CO₃)</td>
<td>26.0</td>
<td>25</td>
</tr>
<tr>
<td>Per cent Na₂O on chips</td>
<td>18.0</td>
<td>14.0</td>
</tr>
<tr>
<td>Ratio of wood to total liquor</td>
<td>1:4.0</td>
<td>1:4.0</td>
</tr>
<tr>
<td>Ratio of wood to black liquor</td>
<td>1:0.7</td>
<td>1:0.7</td>
</tr>
<tr>
<td>Maximum cooking temperature, °F</td>
<td>350</td>
<td>350</td>
</tr>
<tr>
<td>Time to maximum temperature, hours</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Total cooking time, hours</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Per cent screened pulp yield</td>
<td>36.2</td>
<td>38.2</td>
</tr>
<tr>
<td>Per cent screenings, based on chips</td>
<td>0.0</td>
<td>0.4</td>
</tr>
<tr>
<td>TAPPI permanganate number</td>
<td>10.4</td>
<td>16.9</td>
</tr>
</tbody>
</table>
tear results. The degree of bleaching evidently made a great difference in the pulp strengths.

In another series of tests made by the Herty Foundation (52) Phyllostachys bambusoides was pulped in ten cooks under slightly varied conditions, and the resulting pulp was made into 0.009-, 0.014-, and 0.023-inch board; tests were made on board made both from straight bamboo pulp and from a mixture of bamboo and Kraft waste paper in varying proportions. No definite correlation was found between the strength properties of the board and the percentage of bamboo in the pulp; in general, it might be said that the strength decreased slightly with an increasing percentage of bamboo, although in many cases the board from 100 per cent bamboo was found to possess higher strength properties than board from any mixture of bamboo and Kraft waste paper. Tabulated results of these tests are presented in Table XXIX.
**TABLE XXIX-A**

**BAMBOO KRAFT COOKS MADE BY THE HERTY FOUNDATION LABORATORY (52)**

<table>
<thead>
<tr>
<th>Cook No.</th>
<th>Per Cent Chemical as Na₂O</th>
<th>Cooking Time* (Hours)</th>
<th>Cooking Temp. (*F.)</th>
<th>Yield (Per Cent)</th>
<th>Permanganate Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15</td>
<td>2</td>
<td>355</td>
<td>39</td>
<td>27</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>2</td>
<td>355</td>
<td>--</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>1-3/4</td>
<td>355</td>
<td>--</td>
<td>20.1</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>2-1/4</td>
<td>350</td>
<td>40</td>
<td>19.1</td>
</tr>
<tr>
<td>5</td>
<td>12</td>
<td>2-1/4</td>
<td>350</td>
<td>40</td>
<td>23.2</td>
</tr>
<tr>
<td>10</td>
<td>15</td>
<td>2-1/4</td>
<td>355</td>
<td>39</td>
<td>27</td>
</tr>
</tbody>
</table>

*This figure is reckoned from the time a digester pressure of 100 psi is reached.*
### TABLE XXIX-B

**RESULTS OF STRENGTH TESTS ON BAMBOO KRAFT PAPER (52)**

<table>
<thead>
<tr>
<th>Run No.</th>
<th>Thickness of Board Produced (Inches)</th>
<th>Furnish</th>
<th>Moisture (Per Cent)</th>
<th>Average Strengths&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mullen</td>
</tr>
<tr>
<td>1</td>
<td>0.009</td>
<td>100% bamboo</td>
<td>1.6</td>
<td>79</td>
</tr>
<tr>
<td>2</td>
<td>0.014</td>
<td>100% bamboo</td>
<td>4.0</td>
<td>109</td>
</tr>
<tr>
<td>4</td>
<td>0.009</td>
<td>100% bamboo (semichemical)</td>
<td>5</td>
<td>78</td>
</tr>
<tr>
<td>5</td>
<td>0.014</td>
<td>100% bamboo (semichemical)</td>
<td>3</td>
<td>114</td>
</tr>
<tr>
<td>7</td>
<td>0.009</td>
<td>75% bamboo (semichemical)</td>
<td>3</td>
<td>79</td>
</tr>
<tr>
<td>8</td>
<td>0.014</td>
<td>25% Kraft waste paper</td>
<td>5</td>
<td>109</td>
</tr>
<tr>
<td>10</td>
<td>0.009</td>
<td>50% bamboo</td>
<td>5</td>
<td>76</td>
</tr>
<tr>
<td>11</td>
<td>0.014</td>
<td>50% Kraft waste paper</td>
<td>4</td>
<td>101</td>
</tr>
<tr>
<td>13</td>
<td>0.009</td>
<td>25% Kraft waste paper</td>
<td>3.5</td>
<td>75</td>
</tr>
<tr>
<td>14</td>
<td>0.014</td>
<td>75% Kraft waste paper</td>
<td>5</td>
<td>101</td>
</tr>
</tbody>
</table>

(Continued)
### TABLE XXIX-B (Continued)

RESULTS OF STRENGTH TESTS ON BAMBOO KRAFT PAPER (52)

<table>
<thead>
<tr>
<th>Run No.</th>
<th>Thickness of Board Produced (Inches)</th>
<th>Furnish</th>
<th>Moisture (Per. Cent)</th>
<th>Average Strengths&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mullen</td>
</tr>
<tr>
<td>16</td>
<td>0.009</td>
<td>75% bamboo (semichemical) 25% Kraft waste paper</td>
<td>6.0</td>
<td>62</td>
</tr>
<tr>
<td>17</td>
<td>0.014</td>
<td>75% bamboo (semichemical) 25% Kraft waste paper</td>
<td>4.8</td>
<td>115</td>
</tr>
<tr>
<td>19</td>
<td>0.009</td>
<td>50% bamboo (semichemical) 50% Kraft waste paper</td>
<td>5</td>
<td>65</td>
</tr>
<tr>
<td>20</td>
<td>0.014</td>
<td>50% bamboo (semichemical) 50% Kraft waste paper</td>
<td>4.8</td>
<td>102</td>
</tr>
<tr>
<td>22</td>
<td>0.009</td>
<td>25% bamboo (semichemical) 75% Kraft waste paper</td>
<td>4.8</td>
<td>71</td>
</tr>
<tr>
<td>23</td>
<td>0.014</td>
<td>25% bamboo (semichemical) 75% Kraft waste paper</td>
<td>5.0</td>
<td>Over</td>
</tr>
<tr>
<td>25</td>
<td>0.009</td>
<td>100% bamboo (soda)</td>
<td>4.7</td>
<td>72</td>
</tr>
<tr>
<td>26</td>
<td>0.014</td>
<td>100% bamboo (soda)</td>
<td>4.3</td>
<td>103</td>
</tr>
<tr>
<td>28</td>
<td>0.009</td>
<td>25% bamboo (soda) 75% Kraft waste paper</td>
<td>5.0</td>
<td>71</td>
</tr>
<tr>
<td>29</td>
<td>0.014</td>
<td>25% bamboo (soda) 75% Kraft waste paper</td>
<td>4.3</td>
<td>104</td>
</tr>
</tbody>
</table>

(Continued)
### TABLE XXIX-B (Continued)

**RESULTS OF STRENGTH TESTS ON BAMBOO KRAFT PAPER (52)**

<table>
<thead>
<tr>
<th>Run No.</th>
<th>Thickness of Board Produced (Inches)</th>
<th>Furnish</th>
<th>Moisture (Per Cent)</th>
<th>Average Strengths*</th>
<th>Mullen</th>
<th>Tear</th>
<th>Tensile</th>
<th>Porosity**</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>0.009</td>
<td>50% bamboo (soda) 50% Kraft waste paper</td>
<td>5</td>
<td>69             22 10.5 12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>0.014</td>
<td>50% bamboo (soda) 50% Kraft waste paper</td>
<td>3</td>
<td>86             34 18.2 12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>0.009</td>
<td>75% bamboo (soda) 25% Kraft waste paper</td>
<td>1</td>
<td>57             18 7.6 18</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>0.014</td>
<td>75% bamboo (soda) 25% Kraft waste paper</td>
<td>2.7</td>
<td>103            35 18.8 15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>0.009</td>
<td>100% bamboo (14% caustic soda, semichemical)</td>
<td>2.1</td>
<td>74             15 8.5 15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>0.014</td>
<td>100% bamboo (14% caustic soda, semichemical)</td>
<td>3.0</td>
<td>88             25 11.1 15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>0.009</td>
<td>25% bamboo (semichemical) 75% Kraft waste paper</td>
<td>0.08</td>
<td>65             30 10.7 12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>0.014</td>
<td>25% bamboo (semichemical) 75% Kraft waste paper</td>
<td>0.06</td>
<td>89             54 15.9 11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>0.009</td>
<td>50% bamboo (semichemical) 50% Kraft waste paper</td>
<td>1</td>
<td>71             24 11.4 30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Continued)
TABLE XXIX-B (Concluded)

RESULTS OF STRENGTH TESTS ON BAMBOO KRAFT PAPER (52)

<table>
<thead>
<tr>
<th>Run No.</th>
<th>Thickness of Board Produced (Inches)</th>
<th>Furnish</th>
<th>Moisture (Per Cent)</th>
<th>Average Strengths&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Porosity&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>44</td>
<td>0.014</td>
<td>50% bamboo (semichemical)</td>
<td>6</td>
<td>106</td>
<td>39</td>
</tr>
<tr>
<td>46</td>
<td>0.009</td>
<td>75% bamboo (semichemical)</td>
<td>0.06</td>
<td>85</td>
<td>19</td>
</tr>
<tr>
<td>47</td>
<td>0.014</td>
<td>75% bamboo (semichemical)</td>
<td>0.06</td>
<td>97</td>
<td>34</td>
</tr>
</tbody>
</table>

<sup>a</sup> In each case, the material was refined in a 50-lb. beater to 450 cc. freeness (3-gram Schopper-Riegler), and machine variables were kept essentially constant.

Sixteen machine runs were also made producing 0.023-inch board; equipment for Mullen, tear and tensile tests on this material were not available.

<sup>b</sup> This is an air porosity, determined by a method similar to that employed in the Gurley densimeter.
<table>
<thead>
<tr>
<th>Species</th>
<th>Per Cent NaOH Employed&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Liquor Concentration (Per Cent NaOH)</th>
<th>Cooking Treatment Time (Hours)</th>
<th>Cond.</th>
<th>Yield of Unbleached Pulp&lt;sup&gt;a&lt;/sup&gt; (Per Cent)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gigantochloa wrayi</td>
<td>20</td>
<td>4</td>
<td>7</td>
<td>160° C</td>
<td>41</td>
<td>(19)</td>
</tr>
<tr>
<td>Ochlandra ridleyi</td>
<td>20</td>
<td>4</td>
<td>7</td>
<td>160° C</td>
<td>39</td>
<td>(19)</td>
</tr>
<tr>
<td>Arundinaria alpina</td>
<td>16</td>
<td>4</td>
<td>7</td>
<td>160° C</td>
<td>40</td>
<td>(24)</td>
</tr>
<tr>
<td>Arundinaria alpina</td>
<td>20</td>
<td>4</td>
<td>7</td>
<td>160° C</td>
<td>34</td>
<td>(24)</td>
</tr>
<tr>
<td>Bambusa nana (1)</td>
<td>--</td>
<td>--</td>
<td>7</td>
<td>160° C</td>
<td>36</td>
<td>(43)</td>
</tr>
<tr>
<td>Bambusa nana (2)</td>
<td>--</td>
<td>--</td>
<td>7</td>
<td>160° C</td>
<td>34</td>
<td>(43)</td>
</tr>
<tr>
<td>Bambusa tulda</td>
<td>--</td>
<td>--</td>
<td>7</td>
<td>160° C</td>
<td>48</td>
<td>(43)</td>
</tr>
<tr>
<td>Bambusa alpina</td>
<td>--</td>
<td>--</td>
<td>7</td>
<td>160° C</td>
<td>34</td>
<td>(43)</td>
</tr>
<tr>
<td>Mixed Philippine bamboos</td>
<td>11-15</td>
<td>-</td>
<td>4-6</td>
<td>320° F</td>
<td>43-45</td>
<td>(23, 57)</td>
</tr>
<tr>
<td>Bambusa polymorpha</td>
<td>18</td>
<td>-</td>
<td>1</td>
<td>120 psi</td>
<td>46</td>
<td>(187)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>52 psi</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Philippine &quot;dwarf&quot; bamboo</td>
<td>15-20</td>
<td>-</td>
<td>-</td>
<td>--</td>
<td>40-50</td>
<td>(218)</td>
</tr>
<tr>
<td>Philippine &quot;structural&quot; bamboo</td>
<td>15-20</td>
<td>-</td>
<td>-</td>
<td>--</td>
<td>40-50</td>
<td>(218)</td>
</tr>
</tbody>
</table>

(Continued)
TABLE XXX-A (Continued)
SODA PULPING OF BAMBOO

<table>
<thead>
<tr>
<th>Species</th>
<th>Per Cent NaOH Employed&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Concentration (Per Cent NaOH)</th>
<th>Cooking Treatment</th>
<th>Yield of Unbleached Pulp&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bambusa nana</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>(245)</td>
</tr>
<tr>
<td>Unstated</td>
<td>15</td>
<td>4</td>
<td>2</td>
<td>14-28 psi</td>
<td>(34, 272)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7-1/2</td>
<td>57-64 psi</td>
<td></td>
</tr>
<tr>
<td>Phyllostachys bambusoides</td>
<td>18</td>
<td>-</td>
<td>1-1/4</td>
<td>100 psi</td>
<td>(52)</td>
</tr>
<tr>
<td>Phyllostachys bambusoides</td>
<td>14</td>
<td>-</td>
<td>1-1/2</td>
<td>100 psi</td>
<td>(52)</td>
</tr>
<tr>
<td>Phyllostachys bambusoides</td>
<td>14</td>
<td>-</td>
<td>1-1/2</td>
<td>100 psi</td>
<td>(52)</td>
</tr>
</tbody>
</table>

<sup>a</sup> These percentages are based on the weight of air-dried bamboo.
### TABLE XXX-B

**SODA PULPING OF BAMBOO**

<table>
<thead>
<tr>
<th>Species</th>
<th>Per Cent NaOH Consumed&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Yield of Bleached Fulp&lt;sup&gt;a&lt;/sup&gt; (Per Cent)</th>
<th>Bleaching Powder Consumed&lt;sup&gt;b&lt;/sup&gt; (Per Cent)</th>
<th>Remarks</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Gigantochloa grayi</em></td>
<td>11.5</td>
<td>36</td>
<td>—</td>
<td>Bleached to pale cream paper of good strength and quality</td>
<td>(19)</td>
</tr>
<tr>
<td><em>Ochlandra ridleyi</em></td>
<td>11.9</td>
<td>35</td>
<td>—</td>
<td>Bleached readily, yielding white, opaque paper of good strength and quality</td>
<td>(19)</td>
</tr>
<tr>
<td><em>Arundinaria alpina</em></td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Could not be satisfactorily bleached</td>
<td>(24)</td>
</tr>
<tr>
<td><em>Arundinaria alpina</em></td>
<td>—</td>
<td>31</td>
<td>—</td>
<td>Equal to that of soda wood pulp</td>
<td>(24)</td>
</tr>
<tr>
<td><em>Bambusa nana</em></td>
<td>14.7</td>
<td>—</td>
<td>—</td>
<td>Produced white paper of good quality</td>
<td>(43)</td>
</tr>
<tr>
<td><em>Bambusa tulda</em></td>
<td>11.8</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>(43)</td>
</tr>
<tr>
<td><em>Bambusa alpina</em></td>
<td>11.6</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>(43)</td>
</tr>
</tbody>
</table>

(Continued)
### Table XXX-B (Continued)

**SODA PULPING OF BAMBOO**

<table>
<thead>
<tr>
<th>Species</th>
<th>Per Cent NaOH Consumed&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Yield of Bleached Pulp&lt;sup&gt;a&lt;/sup&gt; (Per Cent)</th>
<th>Bleaching Powder Consumed&lt;sup&gt;b&lt;/sup&gt; (Per Cent)</th>
<th>Remarks</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed Philippine bamboos</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>(23, 57)</td>
</tr>
<tr>
<td>Bambusa polymorpha</td>
<td>--</td>
<td>--</td>
<td>10</td>
<td>--</td>
<td>(187)</td>
</tr>
<tr>
<td>Philippine &quot;dwarf&quot; bamboo</td>
<td>--</td>
<td>--</td>
<td>10-20</td>
<td>Cooked under conditions less severe than those of the same process for soft woods</td>
<td>(218)</td>
</tr>
<tr>
<td>Philippine &quot;structural&quot; bamboo</td>
<td>--</td>
<td>--</td>
<td>20-25</td>
<td>Same as above</td>
<td>(218)</td>
</tr>
<tr>
<td>Bambusa nana</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Bleached to cream color</td>
<td>(245)</td>
</tr>
<tr>
<td>Unstated</td>
<td>--</td>
<td>40</td>
<td>16 + 0.3 per cent H₂SO₄</td>
<td>Yielded light cream paper</td>
<td>(34, 272)</td>
</tr>
</tbody>
</table>
TABLE XXX-B (Continued)

SCDA FULPING OF BAMBOO

<table>
<thead>
<tr>
<th>Species</th>
<th>Per Cent NaOH Consumed&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Yield of Bleached Pulp&lt;sup&gt;a&lt;/sup&gt; (Per Cent)</th>
<th>Bleaching Powder Consumed&lt;sup&gt;b&lt;/sup&gt; (Per Cent)</th>
<th>Remarks</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Phyllostachys</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(52)</td>
</tr>
<tr>
<td><em>bambusoides</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Phyllostachys</em></td>
<td></td>
<td></td>
<td></td>
<td>Semichemical process used</td>
<td>(52)</td>
</tr>
<tr>
<td><em>bambusoides</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Phyllostachys</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(52)</td>
</tr>
<tr>
<td><em>bambusoides</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Based on the weight of dry bamboo.

<sup>b</sup> Based on the weight of unbleached pulp.
SUGGESTED INVESTIGATION OF PULPING PROCEDURES
(Excerpt from Progress Report, August 12, 1952)

It has been reported that high caustic content in cooking liquors used for pulping bamboo results in increased screenings. ("Test Cooking Dendrocalamus latiflorus Munro," Tatu Pulp and Paper Mill, Taiwan, China, Discussion - Part d.) This may be an indication that high concentrations damage the bamboo cellulose fibers and that milder conditions would be more advantageous. It is our belief that pulping methods not widely used in this country, as well as relatively new processes, should be investigated, especially those which do not appear to be as harsh as conventional processes, e.g., nitric acid pulping, which has been used for materials such as straw and bagasse. The disadvantage of requiring a finer subdivision of raw material might not prove to be a major problem with bamboos.*

Neutral sulfite pulping, which was used for hardwood pulp at the College of Forestry, State University, Syracuse, New York, might also be considered. [Chemical Engineering 58, No. 4, 184 (1951).] The relatively new method of producing wood pulp by delignification using triethylene glycol or similar solvents is another procedure we think is worthy of consideration. [Chemical Week 61, No. 16, 23 (1951).]

These methods are reputedly less harsh and should cause less damage to the fibers.

---

Complete information on methods might be obtained from those foreign mills that are now commercially producing pulp and paper from bamboos. This would certainly indicate what is successfully being used at present. An investigation of the pulps and papers from these sources might also be made. Since the Taiwan reports have stated that their pulps were not compared to "foreign" pulps because of the lack of standard sheet-forming machinery, it would probably be of value to obtain samples of their pulps and prepare sheets for tests on strength, etc.
TABLE XXXI
SOME USES OF BAMBOO

<table>
<thead>
<tr>
<th>Uses of Culms</th>
<th>Uses of Culms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activated charcoal</td>
<td>Diesel fuel</td>
</tr>
<tr>
<td>Airplane wing members</td>
<td>Dikes, manufacture of</td>
</tr>
<tr>
<td>Alcohol, source of</td>
<td>Edible young shoots (in sprouting season only)</td>
</tr>
<tr>
<td>Antenna supports, radio</td>
<td>Ergot, source of</td>
</tr>
<tr>
<td>Archers' bows, laminated</td>
<td>Erosion preventive</td>
</tr>
<tr>
<td>Arrow tips</td>
<td>Fences and gates, plain and ornamental</td>
</tr>
<tr>
<td>Bakelite-impregnated culms, for various purposes</td>
<td>Fishing poles, ordinary</td>
</tr>
<tr>
<td>Bars for fence gaps (instead of heavy poles)</td>
<td>Fishing poles, split bamboo</td>
</tr>
<tr>
<td>Basketry</td>
<td>Flagpoles</td>
</tr>
<tr>
<td>Bean poles</td>
<td>Flails for harvesting nuts</td>
</tr>
<tr>
<td>Bridges (small or temporary)</td>
<td>Floats for fish nets</td>
</tr>
<tr>
<td>Brooms</td>
<td>Food for certain animals, such as pandas</td>
</tr>
<tr>
<td>Brush handles, for tooth brushes and others</td>
<td>Fruit-tree props</td>
</tr>
<tr>
<td>Buttons</td>
<td>Furniture of many kinds, especially for porch and sun room</td>
</tr>
<tr>
<td>Canes, walking</td>
<td>Handles for shuffleboard cues</td>
</tr>
<tr>
<td>Clothes poles</td>
<td>Handles for tools</td>
</tr>
<tr>
<td>Clothes racks</td>
<td>Hats (finely woven)</td>
</tr>
<tr>
<td>Crates for fruits and vegetables</td>
<td>Huts, in warm countries</td>
</tr>
<tr>
<td>Decorative plantings, hedges, windbreaks (roots of running bamboos must be controlled)</td>
<td>Humidors for tobacco</td>
</tr>
</tbody>
</table>

(Continued)
### TABLE XXXI (Continued)

**SOME USES OF BAMBOO**

<table>
<thead>
<tr>
<th>Uses of Culms</th>
<th>Uses of Culms</th>
<th>Uses of Parts Other Than Culms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ladders</td>
<td>Scaffolding</td>
<td>Culm sheaths—printing pads (barens) for woodcut printing</td>
</tr>
<tr>
<td>Masts for boats</td>
<td>Shade houses for plants</td>
<td>leaves—fodder, deodorization of fish oil</td>
</tr>
<tr>
<td>Matting, woven</td>
<td>Ski poles</td>
<td>Tabashir—catalyst</td>
</tr>
<tr>
<td>Musical instruments, such as shepherd pipes and reeds for woodwinds</td>
<td>Tent poles</td>
<td></td>
</tr>
<tr>
<td>Nails</td>
<td>Trellises</td>
<td></td>
</tr>
<tr>
<td>Ornaments of many types</td>
<td>Vases</td>
<td></td>
</tr>
<tr>
<td>Paper pulp</td>
<td>Vaulting poles</td>
<td></td>
</tr>
<tr>
<td>Phonograph needles</td>
<td>Walking sticks</td>
<td></td>
</tr>
<tr>
<td>Plant labels</td>
<td>Water-conducting pipes, (irrigation, drainage)</td>
<td></td>
</tr>
<tr>
<td>Plant stakes</td>
<td>Waxes</td>
<td></td>
</tr>
<tr>
<td>Plywood</td>
<td>Weapons of various types</td>
<td></td>
</tr>
<tr>
<td>Porch shades</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pots for plants</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Punting poles for boats</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reinforcement for concrete</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rope and cable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rug poles</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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FINAL REPORT
PROJECT NO. 177-170

SURVEY OF THE NEEDS OF INDUSTRY
FOR
RAW MATERIALS FROM NEW PLANTS
TO BE
GROWN IN THE UNITED STATES

By

H. E. SINEATH

- o - o - o - o -

CONTRACT NO. A-18-33685

DIVISION OF PLANT EXPLORATION AND INTRODUCTION
BUREAU OF PLANT INDUSTRY
UNITED STATES DEPARTMENT OF AGRICULTURE

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JUNE 15, 1953
ENGINEERING EXPERIMENT STATION
of the Georgia Institute of Technology
Atlanta, Georgia

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JUNE 15, 1953
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II. PROCEDURE AND RESULTS. ............................... 3
III. CONCLUSIONS AND RECOMMENDATIONS. ................. 8

This Report Contains 12 Pages
I. INTRODUCTION

Through the Research and Marketing Act of 1946, the Bureau of Plant Industry activated in 1947 a national program for the introduction and investigation of new plants of potential value to United States agriculture. Plants which might be utilized by chemical and manufacturing industries were given special emphasis, since diversification of crops might place agriculture in this country in a better economic position. The Georgia Institute of Technology was requested to make a survey of the needs of industry for raw materials from plant sources by C. O. Erlanson, Head of the Division of Plant Exploration and Introduction. The purpose of the survey was to present a comprehensive picture of the raw material needs of industry which could be used as a guide in the search for plants of potential economic value. The survey was designed for two years' study. The first year's work was under Contract No. A-15-33022; the primary objectives under the contract were:

1. A review of the literature to determine the recognized needs which have been published.

2. Direct contact with industry to get first-hand information of industrial raw material needs.

3. After needs had been established, to determine
   a. How much was needed,
   b. The price that could be expected for the material, and
   c. The effect of price on the volume needed for use.

The program designed to accomplish the stated objectives was as follows:
1. A literature survey, compiling the needs which had been published.

2. Contacts through industrial associations.
   a. Correspondence with, and visits to, executive secretaries of groups of such as American Drug Manufacturers Association, Plastic Materials Manufacturers Association, etc., relative to needs.
   b. Attendance of meetings of cooperating groups to contact leaders.
   c. Listing of best companies for detailed contacts from recommendations from a and b.

3. Contacts with research institutes, universities doing industrial research, and government laboratories.
   a. Correspondence.
   b. Visits to discuss needs that have been recognized.

4. Organization of general information obtained in 2 and 3 in order to select obviously promising leads with chances of early results.

5. Visits to outstanding companies in each industry, with special attention to leads from 4.
   a. Talks with technical men concerning recognized needs.
   b. Talks with sales development groups concerning possible new products from new plants.

6. Summary of findings in a report, including recommendations for additional work.

Based on the findings of this program the second year's work under Contract No. A-18-33685 was outlined to include:
1. An extension of the literature survey covering past and current publications.

2. The publication of at least two informational summaries, preferably in bulletin form, based on current literature concerning industrial raw material needs.

3. Market surveys on at least three individual items selected for more detailed study.

This report is intended as a general summary of the work done on this two-year program. Detailed information is not given, but references are made to previous reports submitted under Contract No. A-15-33022 and A-15-33685.

II. PROCEDURE AND RESULTS

During the first year of the program a review of the literature was conducted to determine recognized or published needs for raw materials from plant sources. A secondary object was to locate published information indicating new crops that might have economic value.

Periodicals were selected from a compiled list of publications that were likely to contain pertinent information, and a general scanning survey was made which covered the period from January, 1946, through December, 1951. Numerous needs and various potential sources for raw materials were revealed.


The scanning survey was extended during the second year to include the periods 1930-45 and 1952. The list of publications covered in the previous year was modified when necessary in order to give a
comprehensive coverage of the literature. Additional needs and new raw material sources were disclosed and several new technological developments were reported; these results are presented in detail in Phase Report No. 1, dated December 18, 1952, under Contract No. A-1S-33685.

As an outgrowth of the current literature survey covering the year 1952, two bulletins were published concerning recent developments in plant-derived industrial raw materials. These reports are official publications of the Engineering Experiment Station, Georgia Institute of Technology, and are listed as Bulletins No. 13 and No. 15. These Bulletins were distributed to representatives of industrial concerns, research institutes, governmental organizations, and interested individuals; copies of these publications are included in the Appendix of Phase Report No. 2, dated March 1, 1953, under Contract No. A-1S-33685.

Although not an objective of the program (but in accordance with the policy of the Engineering Experiment Station) an informational summary of the work carried out under Contract A-1S-33022 was published in the March, 1952, issue of the *Research Engineer*.

The preliminary survey of industry was initiated during the first year by directing correspondence to 253 national industrial associations, university research organizations, research institutes, and governmental laboratories. The answers received from this correspondence (a 60 per cent return) led to personal interviews with representatives of various organizations. From these contacts, both written and personal, 67 needs for raw material and 47 industrial organizations as possible sources of information were suggested. This information is presented in detail in Phase Report No. 1, dated July 16, 1951 (Contract No. A-1S-33022).
After reviewing the information presented in Phase Report No. 1, the 47 companies recommended for contact were classified in one of the following groups according to the raw material they use:

1. Oils
2. Fibers
3. Drugs and Pharmaceuticals
4. Waxes, Gums, and Resins
5. Miscellaneous Materials

Also classified in these groups were 711 additional companies which were selected on the basis of their use of raw materials which have been reported as needs. Individual letters were written to all 758 of these companies; answers were received from 454. Personal interviews were conducted with representatives of 37 companies. From both written and personal contacts, 189 raw material needs were suggested. Forty-nine of these needs were considered significant and were discussed in Phase Report No. 3, dated January 22, 1952 (Contract No. A-1S-33022). Volume and price statistics were compiled when available, and estimates were given of the volume needed and the price per unit that could be expected.

In addition to these needs, 23 potential raw material sources were suggested and 13 companies offered their services as evaluation agencies for new material disclosed in their general field of interest.

The work under Contract No. A-1S-33022 was summarized in a Final Report dated March 1, 1952. Included were conclusions and recommendations based on the information obtained from the survey during the period February 12, 1951-February 12, 1952.
After considering the conclusions and recommendations from the Final Report under Contract No. A-1S-33022, three plants were selected for more detailed study. Extensive literature reviews and market surveys were made on bamboos, candelilla, and Simmondsia. The programs were arranged to obtain as much information as possible concerning the history and growth characteristics of each of the plants, and the past, present, and future market potentials of the established and possible future products derived from them.

In the literature surveys on these plants extensive use was made of standard indexes and other secondary sources to locate the pertinent publications; the resulting bibliographies are believed to be the most comprehensive compiled to date on these subjects.

The market surveys were initiated by correspondence with organizations which were known or which could be assumed to have an interest in the selected plants or products from them; included in this list were representatives of experiment stations, government laboratories, research institutes, industrial associations, and industrial concerns. Individuals who were interested in the plants or their products were contacted, also, when their names were encountered either through correspondence or the literature. Additional correspondence was required in some cases, and personal interviews were arranged in instances where it appeared that they would be desirable.

The details of the literature and market surveys on the bamboos, candelilla, and Simmondsia are presented in Phase Report No. 3, dated June 5, 1953, under Contract No. A-1S-33685. In general, information on past uses and possible future market potentials and crop production
are presented for each plant. Also included are discussions of possible future experimental programs for the plants, as well as suggestions for future informational programs. It is believed that the material contained in Phase Report No. 3 (Contract No. A-1S-33685) on the bamboos, candelilla, and Simmondsia represents the most extensive coverage of information on these subjects to date. The data it contains should serve as a valuable guide and detailed reference for future investigators interested in the development of these plants.

During the course of the work under Contract No. A-1S-33685 recommendations have been made concerning future experimental studies on the bamboos. Specifically, fiber length, pulping, and physical properties studies have been suggested. These recommendations were considered by the United States Department of Agriculture for proposed contracts to be conducted at the Herty Foundation, Savannah, Georgia, and Clemson College, South Carolina.
III. CONCLUSIONS AND RECOMMENDATIONS

After reviewing the results of the two-year program as outlined previously, it is believed that the methods employed were satisfactory for obtaining the desired information. Personal contacts were particularly valuable since individuals gave detailed information verbally that they declined to disclose by correspondence. In general, the organizations and individuals contacted were cooperative, but difficulties were encountered in a few instances in that representatives of some organizations were limited by company policy in the amount of information that they could make available to the researchers. This situation usually occurs when one attempts to obtain confidential figures, the release of which could conceivably cause economic repercussions for the company involved. Various market survey techniques were employed when applicable to circumvent the situations, and it is believed that the reported data represent a comprehensive coverage of the information available on the various subjects studied. The methods employed for the survey should be useful as a guide in subsequent studies of this type.

The literature survey reported in Phase Reports Nos. 1 and 2, under Contract Nos. A-1S-33685 and A-1S-33022, respectively, represents an extensive coverage of the literature on industrial raw materials of plant origin covering the period 1930-52. It is believed that further examination of the literature previous to 1930 would reveal little significant information.

Based on the comments received, the bulletins published on the current literature (1952) were well-received and are considered as
useful summaries of recent developments in their respective fields. Future examinations of current literature, with periodic publication of appropriate summaries, should be of considerable value, especially in view of the present strained international conditions.

In the Final Report (dated March, 1952) under Contract No. A-1S-33022 a list of raw material items was given for which the preliminary survey had revealed enough information to permit considering them for more detailed study. These items are:

Chia or perilla oils,
Sesame oil,
Simmondsia oil,
Bamboo,
Khellin,
Candelilla wax, and
Pyrethrum.

As previously noted, industrial surveys of bamboo, candelilla, and Simmondsia have been conducted; these surveys are included in Phase Report No. 3 (Contract No. A-1S-33685). Similar surveys on the other raw material items in the list above should be of value in view of the industrial need for such items and the possible use of the plants from which they are derived for crop diversification in the United States.

One situation encountered in the industrial surveys on bamboo, candelilla, and Simmondsia is that industry has been unaware of the potentialities of these plants and their products. This fact suggests that informational programs should be expanded. Therefore, the publication of results obtained from the industrial surveys conducted is
planned. These publications will be technical bulletins from the Engineering Experiment Station of the Georgia Institute of Technology and will be distributed to representatives of industrial concerns and other interested organizations. It might be advisable to publish parts of this information in some form of popular media.

The results of the industrial surveys on bamboo, candelilla, and Simmondsia have indicated that they have potentials as domestic crops for supplying certain needs of industry. However, before these sources can be developed, some additional information concerning the economics and technology of their production and utilization must be determined. These factors should be determinable through suitable experimental programs, and the potentials appear to be of sufficient magnitude to warrant such investigations.

The studies recommended for these plants are outlined as follows:

1. Studies should be conducted on experimental plantings of candelilla to determine
   a. The proper species and the optimum growing conditions for producing plants of commercial value.
   b. Production cost, including planting, cultivation, and irrigation.
   c. Yields per acre.
   d. Proper harvesting methods, including development studies of harvesting machinery.

2. Methods of processing, handling, and marketing procedures of candelilla and its products should be studied in an attempt to
   a. Improve quality.
   b. Decrease costs.
   c. Improve percentage recovery.
3. Investigations should be undertaken with experimental plantings of *Simmondsia* of sufficient size to determine
   a. The optimum growing conditions and methods for producing *Simmondsia* seed.
   b. Production costs, including planting, care, and irrigation.
   c. Yields per acre and methods for improving yields.
   d. Harvesting methods, including development studies of harvesting machinery.

4. Studies on processing and handling *Simmondsia* should include
   a. Methods and economics of storage and shipment.
   b. Optimum process for oil extraction.
   c. Investigation on hydrogenation of *Simmondsia* oil.
   d. Investigations of other chemical derivatives and byproducts from *Simmondsia*.

5. The physical properties of various species of bamboo should be studied to disclose the optimum curing and processing methods for each end use. This research should include fiber length determinations.

6. Different species of bamboo should be planted in quantities large enough to permit the determination of
   a. The optimum methods of production, including techniques for efficient plantings, and techniques and machinery for harvesting and shipping.
   b. The optimum methods of pulping bamboo for various uses.

After such programs have been completed, correlation of the data obtained should indicate the feasibility of producing these plants as
crops for industrial use. If their production and industrial use were found to be economically feasible, these plants would then be useful in crop diversification and could provide a means for increasing the productivity of large areas of land in the United States.