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TUNG OIL

ECONOMIC AND COMMERCIAL FACTORS IN THE DEVELOPMENT OF A DOMESTIC TUNG OIL INDUSTRY

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FOREWORD

Tung oil has assumed world-wide prominence as an essential raw material. This product, obtained from the seed of a species of tree native to central and southern China, is the best drying and waterproofing oil of vegetable origin known to technical science.

The fact that over 70 per cent of the Chinese annual exportation of tung oil is consumed in the United States demonstrates the progress made by American industries in the employment of this valuable raw material. As high as \$15,000,000 a year has been expended by the United States for supplies of tung oil from China.

The business hazards associated with complete dependence upon a single foreign source of supply, reflected in irregularity of supplies, variance in quality, and wide price fluctuations, even before the World War turned the attention of industrial consumers to the prospects of developing domestic production of tung oil. Successful experimental acclimatization and adaptation of the tung tree in the United States resulted in the planting of extended commercial acreage in the Southern States. The present area (aggregating over 25,000 acres) devoted to tung trees represents a substantial foundation from which to develop this promising infant industry.

Establishment of a tung-oil industry in the United States will undoubtedly be a distinct boon to Florida, Mississippi, and the other Gulf States. The planting phase of this industry represents a splendid contribution to the diversification of southern agriculture, providing an economic use for certain waste and uncultivated land and an added channel of activity for labor in that region. In addition, the erection and operation of mills for the commercial expression of the oil may directly amplify industrial activity in the Gulf States and may tend to encourage the movement of paint and varnish and other consuming industries to southern plant locations.

This monograph is therefore dedicated to the sound development of an activity which serves agriculture as well as industry and whose influence affects directly conditions in the South and indirectly business interests throughout the entire country.

FREDERICK M. FEIKER, *Director,*
Bureau of Foreign and Domestic Commerce.

JUNE, 1932.

TUNG OIL

ECONOMIC AND COMMERCIAL FACTORS IN THE DEVELOPMENT OF A DOMESTIC TUNG OIL INDUSTRY

INTRODUCTION

Tung oil, also known as China wood oil or Chinese wood oil, is one of the most important vegetable oils of the so-called drying-oil group required by United States industries. It has become particularly well known as an essential raw material in the manufacture of varnishes, also for the waterproofing of wood and many other substances. Domestic requirements are at present derived almost exclusively from China, imports during the three years 1928 to 1930 having averaged in value more than \$13,625,000 annually. American demand for tung oil has increased materially during that period, imports having expanded steadily from 83,000,000 pounds in 1926 to over 126,000,000 pounds in 1930. Particular interest has been manifested in this product because of our complete dependence upon China for supplies and the somewhat extensive planting of tung trees in southeastern United States during the past decade, which may provide a substantial domestic supply of this oil during the coming years.

This bulletin proposes to present a study of conditions surrounding the growth and cultivation of tung trees in China, the harvesting of the nuts, the extraction of the oil, its transportation and trade, as well as its commercial history, properties, uses, and present domestic consumption and other related data which may be of interest to grove owners, importers, and industrial consumers. An added feature of this publication is the section outlining the development of planting in the United States and the commercial possibilities of a domestic supply of tung oil.

THE TUNG TREE

BOTANIC SPECIES

Tung oil¹ of commerce is expressed from the seeds of two species of *Aleurites*, belonging to the spurge family. These two species grow in distinct geographic areas in China and differ considerably in appearance and characteristics. The common trade name of the

¹ The terms "China wood oil" and "Chinese wood oil" have gradually been superseded in general usage in the United States and Great Britain since 1923 as a result of successful adaptation of the *Aleurites fordii* to the United States and in some of the British colonies. It was felt that with the development of production of the oil in other countries the reference to China in the name of the oil would be misleading, as well as the inference that the product was a wood oil.

oil was derived from the heart-shaped leaves of the tree, "tung" being the Chinese term for heart.

Aleurites fordii, known in China as tung-yu shu (tung-oil tree), grows abundantly in the territory adjacent to the Yangtze Valley in central and western China. The other species, *Aleurites montana*, or mu-yu shu (wood-oil tree), is indigenous to South China, particularly in the areas in the vicinity of the West River (Si Kiang), and does not thrive in the cooler regions to the north. The so-called southern wood-oil tree is considerably larger than the northern species at maturity and in general has a slower growth and a greater productive life span. It blossoms earlier and has an egg-shaped fruit, sharply pointed and unevenly ridged on its exterior surface. Its seeds are reported to have a smaller oil content, although chemists report little appreciable difference between the oils derived from the two species. The northern species is of particular concern in this survey, since it is the outstanding source of tung oil, accounting for over 90 per cent of the total Chinese tung seed used in tung-oil extraction, and is the type most adaptable to growth in our Southern States.

PHYSICAL CHARACTERISTICS

The tung-oil tree (tung-yu shu) of the northern species is a relatively small tree with a profusion of low-spreading branches. It makes a rapid growth but seldom exceeds a height of 20 to 25 feet at maturity, and the trunks of the full-grown trees range from 6 to 12 inches in diameter. The smooth, pale-gray bark covers a soft white wood. The tree is deciduous, shedding its leaves in the late fall and remaining dormant throughout the winter months. The leaves, which are large and somewhat heart shaped, show some variance in color according to the age of the tree and the season, but are usually a dark shiny green when the tree is full grown.

The tree is highly ornamental, producing during the spring months a profusion of white blossoms with pink and yellow markings near the base of the petals. After the flowering period a round green fruit appears, tough in texture and consisting of a pulpy exterior covering a nutlike shell containing sometimes as low as three but usually five of the oil-yielding seeds. This fruit resembles a large brown walnut in outward appearance when it ripens in September and October. *Aleurites fordii*, as it flourishes in China, has a rather short productive period, beginning to bear seeds 3 or 4 years after planting and continuing for a period of 12 to possibly 20 or more years thereafter.

CLIMATE AND SOIL REQUIREMENTS

In China the largest percentage of tung oil is obtained from wild trees growing in the gorges and hilly country of the interior Provinces up to an altitude of 2,500 feet. The trees may be few and scattered in certain localities and may appear in dense groves elsewhere. Although little difficulty is experienced in the perpetuation of the tree growths, since they seem to flourish in poor soils and are hardy enough to withstand a certain degree of drought and frost, nevertheless it has been demonstrated in plantings in the United States

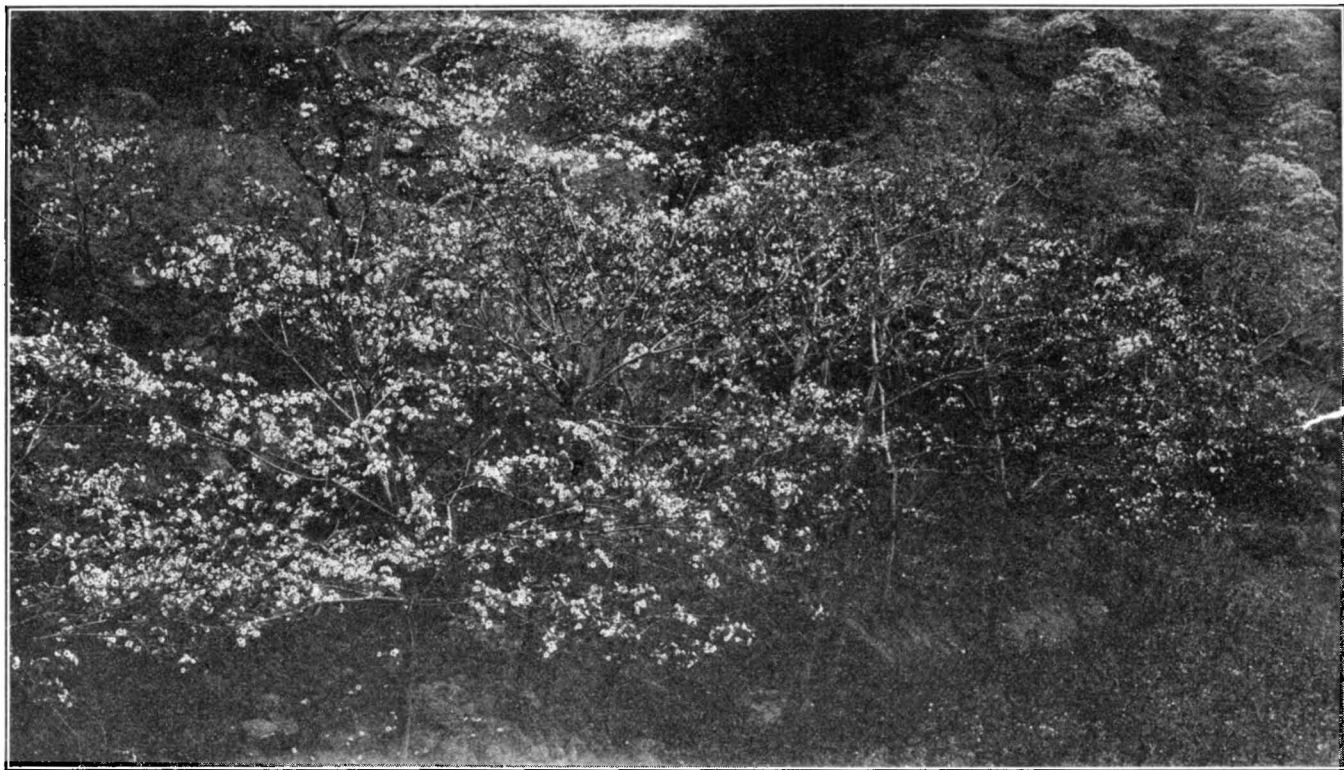


Figure 1.—Wild tung trees in blossom in China.

that favorable climatic and soil conditions have accelerated the growth of the trees, have materially lengthened their productive life span, and have increased the quantity and volume of seed yield per tree.

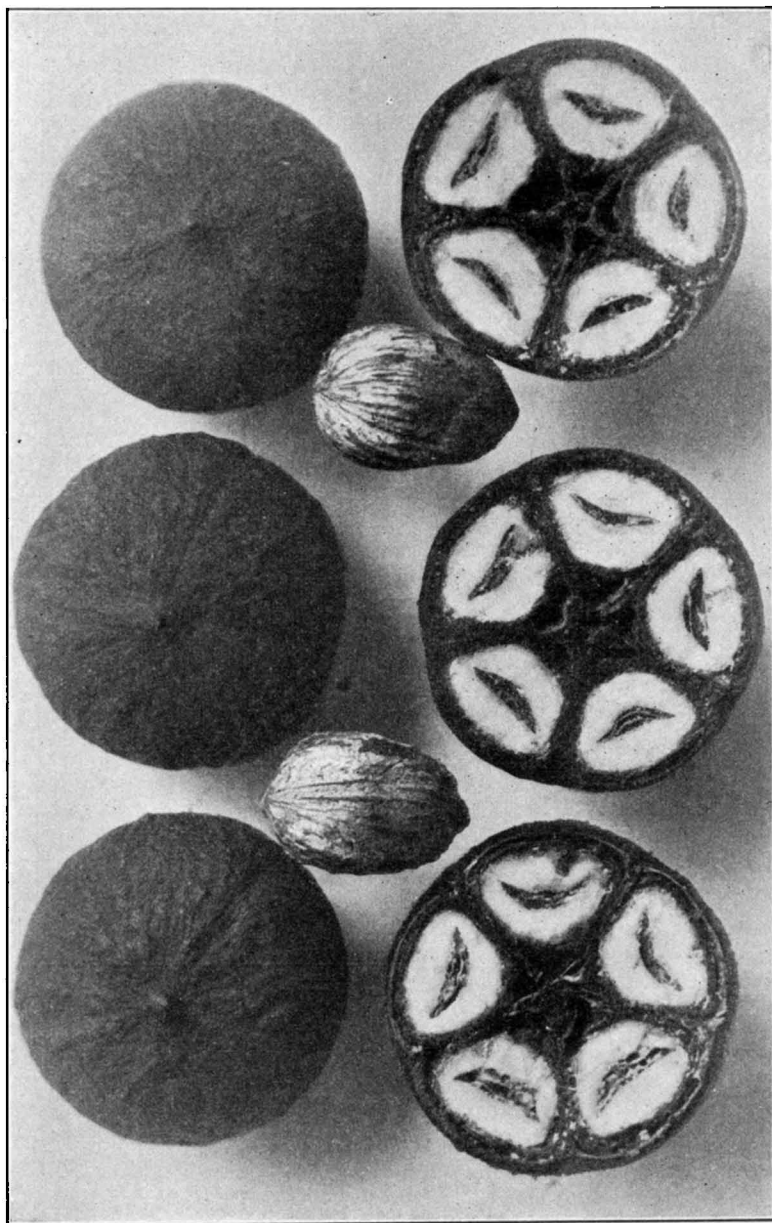


Figure 2.—Tung fruits, showing cross section and individual seeds

TUNG OIL PRODUCTION AND CONSUMPTION IN CHINA

Although tung oil has been an important product of Chinese commerce for several centuries, groves and new planting in China have been largely confined to rocky hillsides, waste places, and roadsides, where farming is difficult. The marked dependence of overpopulated China upon all available arable land for the production of foodstuffs for local consumption, particularly in the interior Provinces, where transportation contact with outside food sources is difficult, has restricted interest in the systematic planting or cultivation of tung trees and other plants yielding industrial raw materials. The small subdivision of land tracts also would tend to limit the development of large plantations in that country.

THE LOCAL INDUSTRY

Chinese farmers have during the past few years displayed a greater interest in tung grove plantings as a means of increasing their profits. The Provinces of Hunan and Kwangsi are probably the most important regions in which cultivation of tung trees has been undertaken. Provincial and National Government authorities are beginning to recognize more fully the importance of tung oil in Chinese economic life and the necessity of additional plantings to meet the increasing demand. Kwangsi authorities in 1929 urged the farmers of that Province to plant tung trees on denuded hills and wasteland or upon their own holdings, and each family was required to set out 300 trees. In Chekiang some well-tended plantations are known to exist, the trees having been grown from seeds without transplanting. During the first and second year cereals and certain other crops have been grown on the plantations without interfering with the growth of the young trees. Also, to maintain profits, the trees are usually felled in the twelfth or fifteenth year, when seed production begins to decline. Fir trees are often planted a few years in advance between the rows of tung trees, and by the time the latter have reached an unproductive stage and are cut down for fuel the firs will have grown into saplings.

The cultivated trees are usually propagated from seeds which are planted initially in a prepared bed about 4 inches deep and from 12 to 20 feet apart, depending upon whether transplanting is contemplated. The seeds begin to sprout after about four weeks, and in summer the young seedlings are covered or shaded with matting to protect them from the sun. At the end of the first year the seedlings may attain a height of 3 feet, and at that time are often transplanted to another nursery bed or replanted in the groves. Plantations containing young trees are weeded and harrowed once or twice a year. The trees, especially the seedlings, are fertilized with wood ash and manure, although after substantial growth the leaves which drop during the late fall are said to provide some humus to fertilize

the trees. The trees usually attain commercial bearing during the fifth year after planting.

HARVESTING AND DELIVERY OF NUTS TO MILLS

The fruit of the tung tree ripens in September or October, depending upon the locality, and may be allowed to fall naturally to the ground at full maturity prior to collection. In many instances, however, the fruit is gathered prematurely, the low stature of the trees enabling workers to pick it or knock it off with long poles.

The fruit is usually collected in large heaps preparatory to husking and removal of the seeds. If exposed to the atmosphere for a sufficient period the husks will either decay or crack open and permit easy removal of the seeds. This process is often accelerated by the covering of the fruit with straw or grass, which causes fermentation and more rapid deterioration of the husk. Other quick-husking operations in common usage in China consist of placing the fruit in a vat of boiling water, which softens the husks or causes them to burst open and permits the seeds to be picked out by hand, or of heating the fruit in iron pans and stirring constantly until well-parched, when the hulls break open.

In Hupeh and Kwangsi many of the farmers or collectors, particularly those living near cities, engage in small-scale oil pressing as side lines. In general, however, the producer or collector of fruit removes the seeds by the primitive husking methods described above, transports them in baskets to small local oil mills, and sells them to the native mill owners.

MILL PROCEDURE AND OIL EXTRACTION

The methods employed in Chinese tung-oil mills are decidedly primitive and have shown little improvement even in recent years. Attempts to establish modern mills in China have in general been met with opposition and have usually been discontinued. Hand labor, in conjunction with crude types of machinery, is employed throughout the tung-oil districts. Cleaning, drying, and pulverizing of the seeds occur prior to actual oil extraction.

CLEANING AND DRYING THE SEEDS

Upon arrival at the mills the tung seeds generally require cleaning and are distributed to men, women, and children engaged to pick out pieces of broken husks and decayed or useless seeds. The seeds are then passed through a hand-made machine which blows out the dust and dirt and allows the clean product to fall into baskets beneath. Cleaning is sometimes accomplished by pouring the seeds from one basket to another in a draughty place and allowing the wind to blow out the dirt as the seeds fall.

After the seeds are considered sufficiently clean they are roasted in large iron pans or in wooden tubs with iron bottoms. Great care is exercised during the roasting to prevent burning, the mass being stirred constantly with a paddle. Moisture is driven off by this process, the seeds become hard and brittle and are then ready to be pulverized. The drying method employed plays a large part in the

resultant color and quality of the oil. Oil dried by the roasting process described is known as hot-pressed oil and is relatively dark in color. In some localities where it is desired to produce a lighter colored oil the seeds are dried in a rudely constructed kiln having a long, horizontal flue, upon which the seeds are placed on wicker frames made of bamboo. Heat is passed through the flue under forced draft, drying the seeds to brittle consistency without discoloration. There is still another method which, although slower, is employed with considerable success during the dry, hot, summer months. This method consists simply of spreading the seeds on the ground in single layers and allowing the sun to dry them. By this process an exceptionally light-colored oil is obtained.

PULVERIZING THE SEED

The next step in the extraction of the oil is the pulverizing of the seeds, which is generally carried out by placing them in a circular

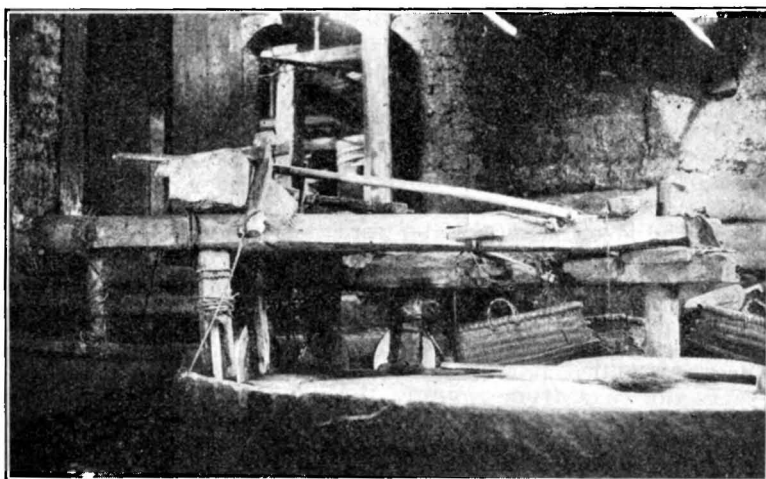


Figure 3.—Grinding mill in China, typical of antiquated methods employed there in pulverizing the tung seed

stone trough, where they are crushed by revolving stone wheels drawn by man, ox, or donkey. Pulverizing or crushing the seeds is sometimes accomplished by using a heavy log constructed in the shape of a hammer, which fits into a large stone or wooden mortar containing the seeds. The lever controlling the hammer is operated by the foot of a coolie who supports himself by ropes suspended from rafters of the building, with his arms inserted in slings, while he works the lever with his feet.

PREPARING THE OIL CAKE

After the seeds are thoroughly pulverized the product is put into steaming vats. These vats are made of wood but have iron bottoms. In the vats water is mixed with the ground seeds, and the resultant mass is steamed until it reaches a soft, mushlike consistency. This mush is then mixed with sufficient straw to hold it together. While this mixture is still hot it is made into round cakes 15 to 18 inches in

diameter, according to the size of the press, and about 4 inches in thickness. A coolie standing on top of a wooden deck presses each cake into three iron hoops about $1\frac{1}{4}$ inches wide. When the mush is made up into cakes, it is then ready for the press. One of the hoops is removed in order to allow the mixture to be compressed without interference from these bands.

EXPRESSING THE OIL

Various methods are employed in China by farmers and oil-mill owners in expressing tung oil from the seed, procedure differing somewhat in the various producing districts. Although Chinese tung-oil presses differ somewhat in construction, capacity, and relative oil yield, they operate on the same general principle and are, at best, very elementary types of machinery.

One of the principal types of oil press employed consists of a huge log supported on a sturdy framework at each end. There is generally an opening 6 to 8 inches wide and 4 to 7 feet long in the side of the log, and the interior is hollowed out to make a space about 15 to 18 inches in diameter running the full length of the side cut. Heavy wooden or stone disks are placed at each end of the cut and the oil cakes are put in horizontally on the flat side through the cut and raised to a vertical position. Large wedges are inserted behind the stone disk and driven by means of a battering-ram log suspended by ropes from the ceiling. Usually an inclined runway is employed in connection with the ram, the coolie or coolies impelling it thus being able to give greater force to the impact. Tremendous pressure is exerted on the cakes in this way, and the oil begins to flow from them into a groove which extends along the bottom of the press. The groove terminates in a hole, through which the expressed oil drops into receptacles.

The straw added at the time the mush is prepared in cake form prevents the cake from running through during the compressing operation. On account of the presence of fine dust and dirt in the expressed oil the product is then strained from one tub to another through coarse grass cloth. Yields of oil from Chinese presses of this type range from 30 to 35 per cent of the weight of the kernel. After the oil is strained it is placed in bamboo baskets, lined inside with many, usually 16, coats of Chinese varnished paper, and covered with the same material. The baskets vary in capacity from 90 catties (120 pounds) to 2.9 piculs (386 pounds), depending upon the locality in which the oil originates.

TUNG-OIL PRODUCTION IN CHINA

Authorities who have dealt with tung-oil production in China in the past have differed considerably in their appraisal of the relative importance of the various Chinese Provinces as producing areas.

SHIFT IN EXPLOITED AREAS

This variance may be partially explained by the apparent marked shift in the comparative standing of exploited areas in China since the World War. It is probable that the rapidly expanding demand in foreign consuming markets which developed during the postwar



Figure 4.—Preparing tung-meal cakes for insertion in press

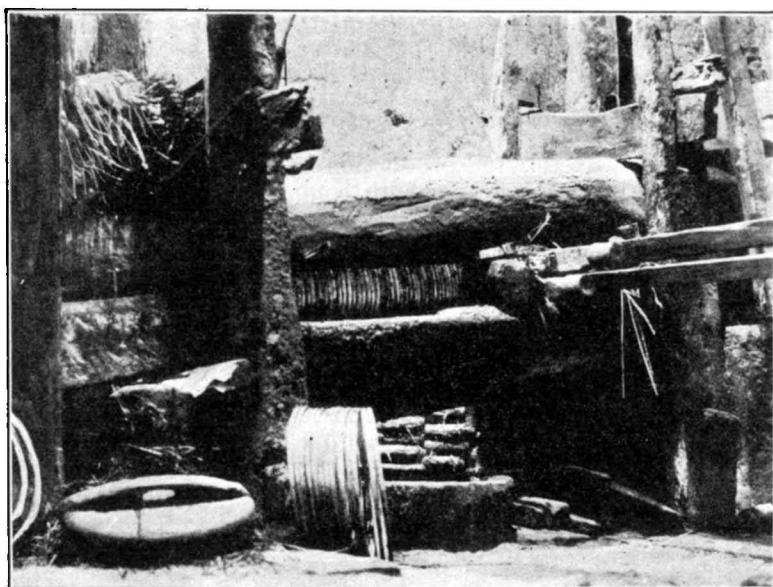


Figure 5.—Typical Chinese tung-oil press

period exhausted or fully accounted for tung-oil production in the lower Yangtze Provinces and in the more accessible producing regions and necessitated collection and expression of the oil from trees far in the interior. Although statistics are not available to bear out a further supposition, it is believed that a greater proportion of the arable land in Central China formerly devoted to tung trees has been turned to food crops essential to the existence of the large and growing Chinese population of the Yangtze Valley, and that interior districts have therefore taken their place as primary sources of tung oil.

Lewkowitsch (in his text, *Chemical Technology and Analysis of Oils, Fats, and Waxes*, published in 1914) stated that "about half of the Chinese tung-oil output is produced in the Provinces of Hunan and Kweichow, about one-third in Szechwan, and the remainder in Hupeh Province near Ichang." Subsequent figures presented in this discussion will indicate the shift which has taken place in producing areas since that time.

Present reports indicate that the tung tree flourishes in China in a region between 23° and 33° north latitude and between 100° and 120° east longitude, or, in general, in sections of a total area embracing approximately 687,000 square miles. The hardier northern species (*Aleurites fordii*) grows principally in the Yangtze Valley, while the other species (*Aleurites montana*) thrives in South China. The principal Provinces producing tung oil from the northern species (*Aleurites fordii*) grows principally in the Yangtze Valley. Kwangsi Province is the leading source of the oil derived from the tropical variety.

In recent years the natives of Kwangsi have imported *Aleurites fordii* from Central China and have grown that species with considerable success in the northern part of the Province near Kweilin. Oil from that species may in the coming years become relatively more important in the export trade of South China.

PRODUCTION BY PROVINCES

Details of Chinese tung-oil production by Provinces, according to recent trade estimates, together with comparative figures compiled by the International Institute of Agriculture at Rome for the year 1914, are shown in the following table.

ESTIMATED PRODUCTION OF TUNG OIL IN CHINA, BY PROVINCES, 1914 AND 1929

[Tons of 2,000 pounds]

Province	1929	1914 ¹	Province	1929	1914 ¹
Szechwan.....	36,650	8,318	Kwangsi.....	8,350	3,600
Hunan.....	33,350	9,421	Other Provinces.....	1,650	9,659
Hupeh.....	20,000	3,541			
Chekiang.....	13,500	9,242	Total.....	112,300	43,783

¹ Statistics taken from *Oleaginous Products and Vegetable Oils, Production and Trade*, published in 1923 by the International Institute of Agriculture at Rome.

The item "Other Provinces" includes principally Kweichow, Shensi, Kiangsi, Kwangtung, Anhwei, and Fukien. As may be seen, some of these regions were formerly relatively important sources of

tung oil. In 1914 Kweichow reported an output of 4,553 short tons; Shensi, 1,159 tons; Kiangsi, 1,131 tons; and Kwangtung, 1,297 tons; while in 1929, the six Provinces combined supplied only 1,650 short tons.

The present Chinese producing regions are shown in Figure 6, to allow a clearer visualization of the important tung-oil districts and the movement of the oil to local extracting mills and thence to collecting and exporting centers.

COLLECTION AND TRANSPORTATION TO EXPORT CENTERS

In view of the inadequate transportation facilities in the tung-oil districts and the scattered tree growths owned by a multitude of small Chinese landowners and farmers, centralized expression of tung oil in China has not proved feasible. On account of the labor required and the relatively high cost of transportation involved in shipping the nuts, native oil mills have been established in the Upper Yangtze, Han, and West River districts, either in small communities or in important collecting centers adjacent to the producing districts. Each mill takes only the tung-nut output of the immediate vicinity, and after expressing the oil sells its output to one of the Chinese dealers located in the nearest collecting or shipping town.

MAIN PRODUCING AREAS

In the following discussion of the leading tung-oil producing districts of each Province the outstanding collection centers in each region are mentioned, indicating in general the extent of the areas from which they receive tung oil and the routes followed by the oil in transit to the major export markets at Hankow and Hong Kong.

SZECHWAN

In Szechwan Province the principal areas exploited for tung oil are located adjacent to the Yangtze and its tributaries. The most westerly producing region in the Province extends upriver from Luchow about 200 miles, northward up the Min River to a little distance beyond Kiating, and southward to the Kweichow provincial boundary. Oil from this district is customarily collected at Luchow and forwarded downriver to the more important trading centers at Chungking and Wanh sien, where it is generally sold to representatives of Hankow export firms or purchased by native produce merchants and traders for shipment to the Hankow market.

Another important tung-oil district in Szechwan is situated in the valleys of the Kialing River, extending from Hochow for several hundred miles north up the three branches of this river system. Chungking, located in a strategic position at the junction of the Yangtze and Kialing Rivers, is the collecting and transshipment port serving this area. Oil is also collected in Chungking from certain smaller upriver producing areas situated to the south of the Yangtze and as far west as Hokiang.

A third outstanding concentration of tung-oil milling centers is in the territory surrounding Wanh sien. This district is said to extend northward to Tungsiang and Chengkow and southward to the

Hupeh border. Wanh sien serves as a collecting and trading port for oil consignments from the important upriver producing centers of Chungchow and Fuchow. Through Fuchow, en route to Wanh sien, passes a large share of the output of the considerable number of producing towns in the southeastern tip of Szechwan and northeastern Kweichow.

HUPEH

The principal tung-oil districts of Hupeh are located in the western portion of the Province. Two regions are outstanding—one in the extreme north, west of Laohokow, and the second in a strip 50 to 100 miles wide on both sides of the Yangtze, extending westward from Shasi as far as the Szechwan boundary line. The production of the first district mentioned is concentrated principally at Laohokow for shipment down the Han River to Hankow, while the output of the latter is collected mainly at Ichang and Shasi.

SHENSI

The tung-oil area in Shensi is confined to the southern portion of the Province in sections of the region on both sides of the Han River up to the Tsinlingshan Mountains. The oil produced is expressed at Tzeyang, Hingan, and several other local centers, and is then transported by junk via the Han River to Hankow.

HUNAN

In Hunan tung oil is produced mainly in the area adjacent to the Yuen River in the northwestern part of the Province, and in the middle-southern portion along the upper course of the Siang River. Hunan tung oil is usually marketed initially by the smaller mill towns in the collecting ports of Changteh and Changsha and is re-shipped across Tungting Lake to Yochow and thence to Hankow for export.

KWEICHOW

Production of tung oil in Kweichow is carried on mainly in the southern and extreme eastern portions of the Province. The output of this Province is marketed and shipped over several different routes, depending upon the location of the milling center. The main routes are (a) through Fuchow on the Yangtze, (b) down the Yuen River to Changteh, or (c) by way of the Cassia River (Kwei Kiang) to Wuchow and thence to Hong Kong.

KWANGSI

Production of tung oil in Kwangsi Province is concentrated mainly in two general regions—one in the southwest, on both sides of the West River above Nanning, and the other in the northeastern districts from the Ping and Lu Rivers to the Kwangtung provincial boundary. The output of South China is collected principally in Nanning on the Si Kiang, Liuchow on the Lung Kiang, and Wuchow on the West River, where the oil is customarily clarified and graded for distribution to either the local or the export market.

The oil is usually traded or sold through brokers in Canton, the bulk of export consignments being forwarded through the British port of Hong Kong.

KWANGTUNG AND KIANGSI

These Provinces are not important factors in the tung-oil trade. According to information at hand, it appears that very little oil is produced in this region, and growths of Aleurites are not extensive. The small quantity of oil produced is consumed locally.

CHEKIANG AND ANHWEI

Although the major portion of the Chinese tung-oil output originates in the Upper Yangtze districts, Chekiang, an eastern coastal Province, produces an appreciable quantity. Anhwei Province, although of small consequence as a tung-oil area, ships practically all its production to collecting and marketing centers in Chekiang, thus amplifying somewhat the stocks available for disposal there. However, the bulk of the production of these two Provinces is marketed in the leading industrial cities of Chekiang and Kiangsu Provinces. Only a small share of the output of this eastern region is contributed to the Chinese export trade in tung oil, as may be seen from figures presented later, showing original exports of the commodity from Shanghai and Wenchow. (See p. 15.)

The principal tung-oil districts of Chekiang are located in the mountainous regions in the southern and eastern sections of the Province and in the Tsien Tang River Valley, although certain quantities are obtained in the vicinity of Hangchow. The production of Anhwei originates mainly in the southern tip of the Province. The export output of central and eastern Chekiang is routed customarily to Hangchow and thence by rail to Shanghai, while Wenchow is the primary trading and shipping center of the southern districts of the Province.

FUKIEN

Tung trees are reported in scattered localities in Fukien Province, particularly in the vicinity of Changchow, but as far as is known these growths are not exploited to any degree, and the Province has not attained a significant position in either local or export trade in the oil.

YUNNAN

Yunnan Province, although possessing a fair number of tung trees in the heavily forested areas to the northeast and northwest, has not become an important source of supply because of the scattered growths and the difficulties involved in transporting oil to the export centers. Yunnan is without a seaport, and the only feasible means of transportation to the coast is via the French-owned Yunnanfu-Haifong Railway.

The fact that a distance of less than 200 miles separates the tributaries of the Yangtze from the headwaters of the West River would account for considerable Kweichow and southern Hunan oil entering the Kwangsi market under disturbed political, military, or climatic conditions affecting Yangtze outlets. Recent road construction con-

necting West River ports with tung-oil sections in those Provinces may tend to encourage the regular shipment of tung oil from Hunan and Kweichow through South China ports.

SHIPMENTS FROM LEADING COLLECTING CENTERS

The following table shows the relative importance of the principal tung-oil collecting centers, as indicated by statistics for the years 1926 to 1930, showing original port of shipment of tung oil destined for export to foreign countries or other Chinese ports.

TUNG-OIL SHIPMENTS FROM PRINCIPAL CHINESE COLLECTING CENTERS, 1926-1930

[In piculs; 1 picul=133½ pounds]

Collecting center	Province	1926	1927	1928	1929	1930
Yangtze ports:						
Yochow.....	Hunan.....	328,836	247,686	399,271	471,587	450,654
Hankow.....	Hupeh.....	324,587	325,250	415,152	284,553	228,112
Wanhsien.....	Szechwan.....	178,366	193,472	324,492	263,340	312,555
Chungking.....	do.....	55,493	61,194	35,906	110,907	169,816
Changsha.....	Hunan.....	46,008	37,193	23,155	38,606	29,267
Ichang.....	Hupeh.....	42,661	39,656	49,633	27,264	64,705
Shasi.....	do.....	27,541	16,754	29,425	19,332	28,265
Kinkiang.....	Kwangsi.....	5,839	464	2,490	6,501	1,541
Coastal ports:						
Shanghai.....	Kiangsu.....	8,309	13,665	29,430	25,305	26,081
Wenchow.....	Chekiang.....	15,734	28,008	22,081	35,913	29,812
South China ports:						
Wuchow.....	Kwangsi.....	56,498	103,327	113,775	101,495	57,092
Nanning.....	do.....	16,070	29,695	24,456	21,237	
All other collecting ports.....		10,451	8,021	4,472	15,054	20,012

HANKOW THE LEADING TUNG-OIL TRADING AND SHIPPING CENTER

The port of Hankow, located on the north bank of the Yangtze River approximately 600 miles from its mouth, is under normal conditions the ultimate point of destination of the Yangtze Valley tung-oil production and is the principal tung-oil market in China. From 80 to 90 per cent of the entire tung-oil production of the country is handled at that port for reshipment to other Chinese ports or to foreign consuming countries. The importance of Hankow as an export center may be seen from the following statistics.

HANKOW TUNG-OIL EXPORT TRADE, 1927-1931

[Thousands of pounds]

Year	Total exported to foreign countries	Shipped to United States
1927.....	98,004	73,139
1928.....	124,255	100,285
1929.....	121,341	103,563
1930.....	138,912	114,544
1931.....	94,266	72,072

Because of the difficulties encountered by steamers and large boats in navigating the Yangtze River above Hankow during certain periods of the year, most of the oil brought in from upriver points is transported on small junks or sampans in baskets, tubs, or even in

old kerosene tins. The oil is generally unloaded at Hankow by coolies, who carry the baskets, suspended on bamboo poles, to the godown or warehouse for storage or refining.

PREPARATION OF THE OIL FOR EXPORT

Oil arriving at Hankow generally requires clarification in order to bring it up to desired export quality. The so-called refining process usually consists of pouring the oil into iron storage tanks with conical bottoms, erected on concrete foundations. The capacity of the tanks is from 30 to 1,500 tons. These tanks, equipped with steam coils, are heated thereby and the suspended impurities are precipitated; the clarified oil can then be drawn off through faucets



Figure 7.—Delivering tung oil to warehouse on arrival at Hankow

arranged at various heights on the side of the tank. The remaining oil, containing sediment, is run out from bottom faucets.

During the winter months tung oil is generally shipped by lighter to Shanghai for loading to tankers, but in summer ocean steamers come direct to Hankow for loading. The oil is generally loaded into the ship tanks by pipe lines, or from lighters anchored beside the larger vessel. Shanghai, although primarily a reexport point for shipments from Hankow, receives small quantities of oil from producing areas east of Hankow.

HONG KONG THE CHIEF TRADING AND TRANSSHIPMENT CENTER OF SOUTH CHINA

Although oil produced in Kwangsi Province is ultimately collected and warehoused at Wuchow and Canton, actual sales for export ship-

ment are customarily transacted through Hong Kong merchants. Therefore that port is the leading tung-oil trading and shipping port of the South China area. The volume of business handled in Hong Kong shows considerable variance from year to year in reflecting changes in the volume of production in Kwangsi Province, quantity of supplementary shipments from southern Hunan and Kweichow, and transportation conditions on the West, Red, and Cassia Rivers, which serve the Hong Kong tung-oil area. Disturbed political conditions and military movements on the Yangtze diverted considerable oil from that region to the Hong Kong market during 1927 and 1928.

The following table shows the exports of tung oil from China to Hong Kong during the period 1921 to 1930 and indicates the portion of the total tung-oil trade passing through that port during each of the 10 years. Although the largest volume of shipments was received during 1928, a higher percentage of the total tung-oil trade was handled in 1927.

EXPORTS OF TUNG OIL FROM CHINA TO HONG KONG, 1921-1930

Year	Pounds	Per cent of total tung-oil trade handled at Hong Kong	Year	Pounds	Per cent of total tung-oil trade handled at Hong Kong
1921.....	6,365,466	11.3	1926.....	7,137,733	7.1
1922.....	6,010,800	6.0	1927.....	17,824,400	14.8
1923.....	14,510,000	13.0	1928.....	18,448,533	12.7
1924.....	9,848,733	8.2	1929.....	16,638,067	11.7
1925.....	3,870,760	3.2	1930.....	7,390,266	4.8

The collection and publication of trade figures was discontinued by the Hong Kong government on July 1, 1925, and was not again undertaken until April 1, 1930. Therefore official statistics showing exports of tung oil from Hong Kong are not available for that period. However, declared export returns of shipments to the United States during those years will suffice to indicate the volume of the trade.

EXPORTS OF TUNG OIL FROM HONG KONG DECLARED FOR SHIPMENT TO THE UNITED STATES, 1925-1929

Year	Pounds	Approximate per cent of total shipments from Hong Kong destined to United States ¹
1925.....	1,520,000	40
1926.....	2,818,000	40
1927.....	10,680,763	60
1928.....	11,984,748	65
1929.....	10,408,000	62

¹ Relation of exports declared as destined for the United States to annual shipments from China to Hong Kong.

During the four years 1921 to 1924, when official figures were obtainable, shipments destined to the United States accounted annually for only about 30 to 35 per cent of the total Hong Kong tung-oil trade. Since that time there has apparently been a marked increase in the proportion exported to the United States. Trade estimates published by the Hong Kong Chamber of Commerce placed the total export of tung oil during 1929 at 9,000 tons, of which nearly 60 per cent was shipped to the United States. Official statistics available during the 9-month period April to December, 1930, record total shipments of 4,725,000 pounds of tung oil from Hong Kong, over 60 per cent of which was consigned to American consumers.



Figure 8.—Tung-oil junk in Upper Yangtze River

However, during the entire year 1931, of the total 7,670,130 pounds of tung oil shipped to all countries from the port of Hong Kong, less than 50 per cent was destined to the United States. Of the remainder, 14 per cent was destined to the Netherlands, 10 per cent to Germany, 7 per cent to the United Kingdom, 5 per cent to Australia, and 4 per cent to Japan.

THE YANGTZE RIVER AS A FACTOR IN TUNG-OIL TRADE

The Yangtze, one of the great rivers of the world, is the principal channel over which tung oil passes to the primary market for export shipment. A summary of conditions encountered in transporting this commodity from upriver ports on the Yangtze will illustrate the difficulties involved in shipping the oil prior to its receipt at Hankow.

From its mouth the river is navigable 1,600 miles inland to Suifu during 8 months of the year; although Chungking, some 1,300 miles west of Shanghai, is considered the head of navigation for small steam and motor vessels. Ocean-going vessels may safely navigate

the river between Shanghai and Hankow during high water from July to September. Navigation is extremely hazardous in the series of gorges upriver from Ichang to Suifu. Strong currents, frequent rapids, narrow channels, whirlpools, backwashes, and wrecked hulls of ships are listed among the perils to be passed. For these reasons junks and small-draft vessels carry practically all the tung-oil output of the upriver districts, although during the summer months fair-sized motor vessels transport a portion of the shipments from Ichang, Shasi, and Yochow, to Hankow.

The river at high water often overreaches its banks and floods portions of the adjacent territory. This occurrence makes transportation by way of these waters more difficult and also may tend to injure tung-nut crops in the immediate vicinity of the Yangtze and its tributaries.

CONSUMPTION OF TUNG OIL IN CHINA

Tung oil has been consumed in China for many centuries, being used principally (a) for calking and repairing Chinese junks and small boats; (b) as an ingredient for leather dressing; (c) in the manufacture of soap and varnish; (d) for waterproofing paper, cloth, shoes, umbrellas, silk, pongees, and other materials; and (e) as an illuminant. Present consumption of tung oil in China is estimated at 700,000 piculs (approximately 47,000 short tons), or about 40 per cent of the total production.

While formerly domestic outlets were of primary concern in the Chinese tung-oil trade, the rapid development of foreign trade in this commodity since the World War has resulted in the more extended exploitation of the trees, has changed considerably the distributive organization of this trade, and has relegated the Chinese market to a position of secondary importance. Doctor Lewkowitsch, in his text published in 1914, stated that consumption of tung oil in China was estimated to be at least double the amount exported. The following table depicts clearly the decline in the relative importance of Chinese domestic trade, presenting figures showing the total shipment of tung oil from collecting centers during the years 1921 to 1929 inclusive, in contrast with the net export to foreign countries and the net import into Chinese ports.

CHINESE DOMESTIC TRADE IN TUNG OIL, 1921-1929

[In piculs; 1 picul = 133½ pounds]

Year	Total recorded shipments of tung oil from producing areas	Net export to foreign countries	Net import into Chinese ports	Per cent consumed in China
1921.....	785,995	419,549	341,231	43.4
1922.....	1,098,805	745,565	404,441	36.8
1923.....	1,284,900	836,887	454,639	35.4
1924.....	1,321,479	896,038	366,152	27.7
1925.....	1,276,562	894,073	398,173	31.2
1926.....	1,116,393	748,184	345,183	30.9
1927.....	1,104,385	901,294	224,341	20.3
1928.....	1,473,838	1,094,299	359,055	24.4
1929.....	1,421,094	1,069,650	294,636	20.7
1930.....	1,417,912	1,167,255	265,619	18.7

The net import figures presented in the foregoing table represent rather accurately the consumption of tung oil in China, exclusive of the quantity used in the producing areas in spot consumption. It may be estimated that from 15 to 20 per cent of the total production is consumed in the native Provinces without shipment.

DOMESTIC DISTRIBUTION OF TUNG OIL

It may be interesting in analyzing consumption of tung oil in China to study the net receipts by individual ports as an index to regional demand and existing industries in the territories of those ports which might be serving as outlets for this commodity.

CHINESE DOMESTIC TRADE IN TUNG OIL, SHOWING NET IMPORTS BY PORTS, 1925-1930

[In piculs; 1 picul=133½ pounds]

Port	Province	1925	1926	1927	1928	1929	1930
Chinkiang	Kiangsu	96,439	114,203	52,277	98,568	91,951	64,871
Shanghai	do	66,640	57,671	35,710	47,187	46,988	69,933
Hankow	Hupei	108,265	43,402	38,022	103,230	46,593	
Tientsin	Hopeh	28,117	27,667	40,482	31,778	38,225	51,073
Wuhu	Anhui	21,385	17,745	7,510	17,376	14,437	15,303
Hangchow	Chekiang	16,840	15,107	14,562	16,097	14,349	11,028
Kiaochow	Shantung	6,789	8,609	8,870	9,426	11,441	15,269
Soochow	Kiangsu	6,675	6,662	3,326	4,476	5,811	3,636
Chefoo	Shantung	8,334	7,808	7,418	6,754	5,535	7,061
Canton	Kwangtung	8,624	14,517	4,033	1,270	1,055	1,436
All other ports		32,065	31,792	12,131	22,893	18,251	26,009

CHINESE EXPORT TRADE IN TUNG OIL

The history of the development of Chinese foreign trade in tung oil is interwoven with romance and intrigue. Marco Polo, in reporting on his overland visit to the Orient in the thirteenth century, referred to a certain wood oil used by the Chinese in mixture with lime and chopped hemp for calking their ships. Although tung oil had been employed by the Chinese for many centuries, it did not become a product of foreign commerce until 1516, when Portuguese traders visited Canton and in exchange for European articles received, among other merchandise from the Chinese, what they designated as China wood oil. It was largely through the efforts of the early European seamen and explorers who ventured into the then uncharted seas of the Orient to trade in spices and other valuable products of China and the Indies that a regular trade in tung oil later developed. The early European tung-oil trade was carried on principally with Macao, Canton, and other near-by ports in South China. However, an appreciable trade in tung oil was not developed until the middle of the nineteenth century, and its greatest expansion has been recorded since the World War.

VALUE AS AN EXPORT COMMODITY

During recent years tung oil has assumed a position of outstanding importance in the foreign commerce of China, ranking seventh in point of value among the individual commodities exported from that country. The following table shows the growth of the Chinese trade in tung oil since the World War.

EXPORT TRADE OF CHINA IN TUNG OIL, 1914-1930

Year	Quantity in piculs ¹	Value in Haikwan taels	Average annual exchange rate of Haikwan tael in United States currency
1914-1918 (average)	430, 920	4, 614, 375	
1919	613, 455	7, 960, 968	\$1. 39
1920	540, 716	6, 739, 191	1. 24
1921	419, 549	5, 466, 430	. 76
1922	745, 565	10, 888, 130	. 83
1923	836, 887	17, 477, 421	. 80
1924	896, 038	17, 714, 713	. 81
1925	894, 073	17, 450, 104	. 84
1926	748, 184	14, 962, 313	. 76
1927	901, 294	21, 970, 947	. 69
1928	1, 094, 299	23, 302, 221	. 71
1929	1, 069, 650	23, 519, 702	. 64
1930	1, 167, 255	30, 546, 872	. 46

¹ 1 picul equals 133½ pounds.

MONTHLY FLUCTUATIONS

Total export figures for tung oil do not indicate any marked recessions in the growth of China's foreign trade in this commodity. This trade, stabilized largely by an insistent and ever-increasing foreign demand, has surmounted many difficulties and barriers in the

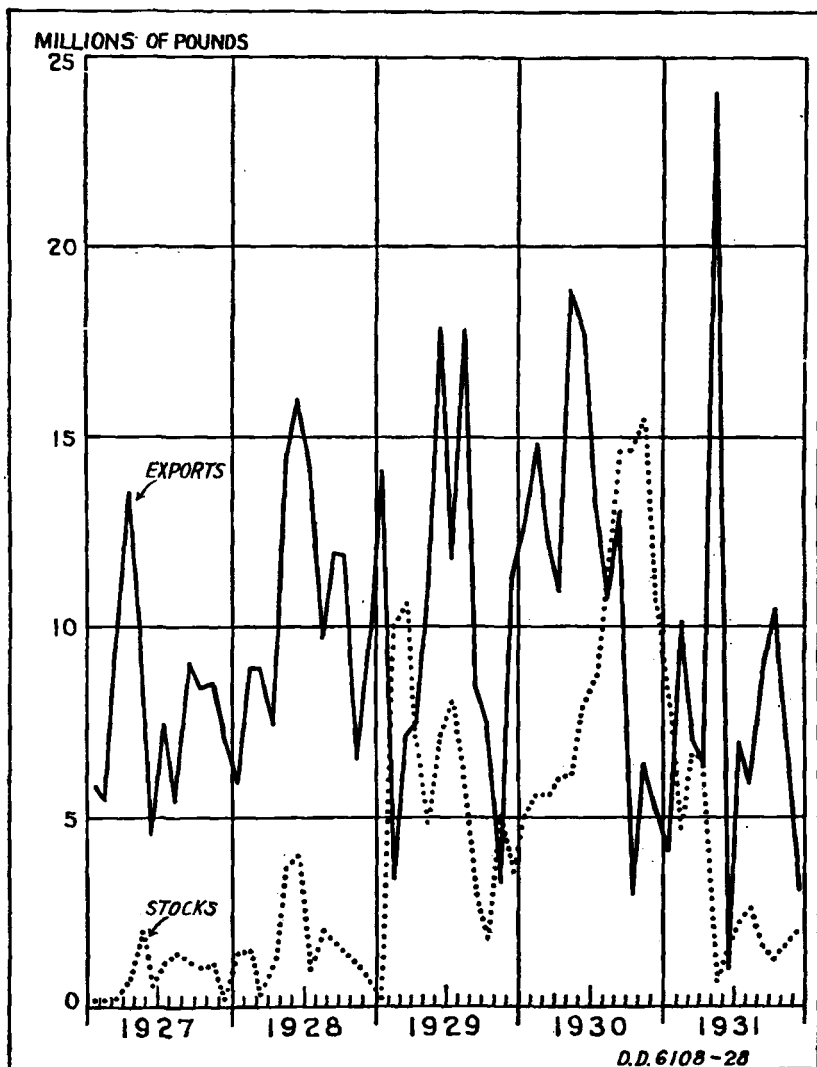


Figure 9.—Hankow monthly tung-oil exports and stocks, 1927-1931

course of its development. Analyzed on a month-by-month export basis, the trade has been decidedly spasmodic, regular seasonal trends having been disturbed by irregular arrivals, fluctuating foreign demand, price speculation, competitive bidding on existing stocks, inadequate transportation facilities, military movements, internal taxation, and many other factors.

Figure 9 shows the marked fluctuations of Hankow exports and stocks of tung oil by months during the period from 1927 to 1931.

It will be observed that, in general, peak shipments of tung oil were recorded during the months of May, June, July, and August. Stocks have varied greatly from month to month, following somewhat closely the fluctuations in export demand and indicating with some degree of accuracy the excess of arrivals at Hankow over export shipments during certain periods. Large exports during May, 1931, were due principally to the announcement of an increased Chinese export duty on tung oil, which took effect on June 1.

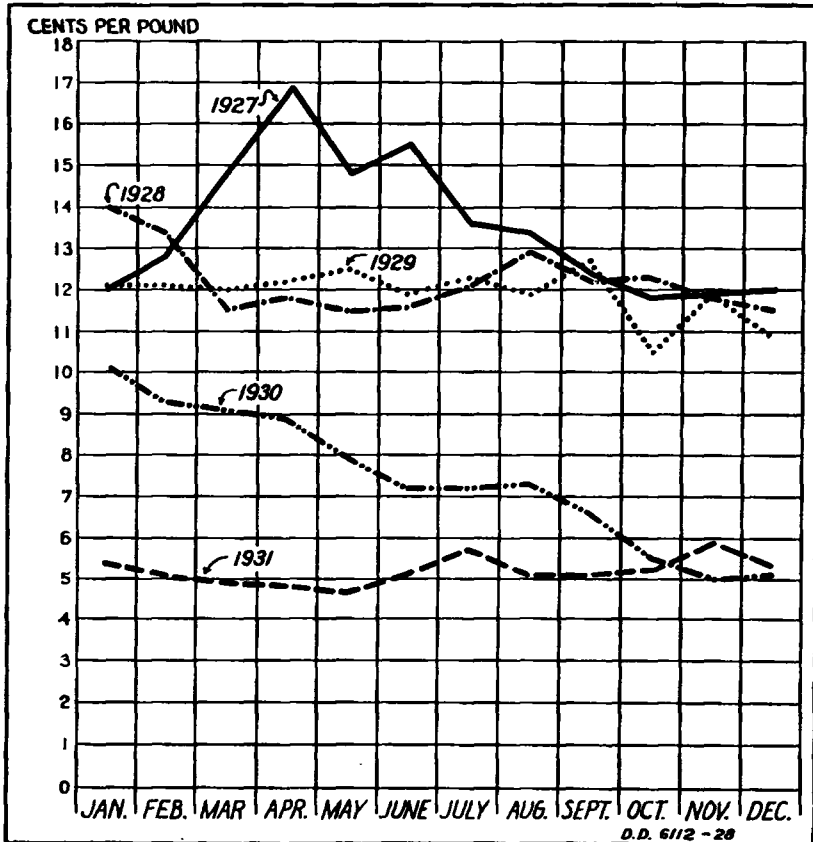


Figure 10.—Monthly trend of tung-oil prices at Hankow, 1927-1931

PRICE CHANGES AS PARTIAL INDEX TO MARKET CONDITIONS

Chinese tung-oil quotations have shown great variance during the past 10 years. Prices naturally were subject to certain normal changes during the period, predicated upon present or anticipated volume of production, existing stocks, foreign demand, and other incident factors. Disturbed political conditions and military movements in China, as they influenced production or movement of oil to export centers, have been more directly responsible for the marked fluctuations which have occurred in prices, particularly evident during 1923 and the early months of 1927.

Figure 10 shows the monthly trend of prices for tung oil at Hankow during the years 1927 to 1931, inclusive.

Fairly normal conditions prevailed in China during 1928 and 1929 and, as will be observed from Figure 10, Chinese prices remained fairly constant. A large output of oil in China and substantial stocks in foreign countries, coupled with the general industrial retrenchment and resultant restricted buying in consuming markets, brought about a steady decline in prices during 1930. Chinese producers and banking interests were reported to have sustained heavy losses in clearing tung-oil stocks during that year. Foreign demand was inactive during 1931, and Chinese prices remained at a very low level. Rumors of foreign plantings and development of groves in the United States have doubtless influenced price reductions to a degree during recent years.

Different means have been employed to stabilize tung-oil prices. Improvements in marketing organization and purchasing methods, standardization of tung-oil shipments, better transportation facilities, and lower freight rates have all aided in a measure in stabilizing the trade and have indirectly affected oil quotations. Improved and more timely information from the principal Chinese tung-oil export center at Hankow has had, it is believed, a definite influence in stabilizing tung-oil prices. In 1925, at the request of the American Paint and Varnish Manufacturers Association, a monthly tung-oil cable service from the American consulate at Hankow to the Chemical Division of the Bureau of Foreign and Domestic Commerce at Washington was initiated. This cabled report contains market quotations of tung oil at Hankow for the month under review, as well as estimates of total monthly exports and stocks. Quotations are expressed in foreign units of quantity and value, and conversions (based upon current cabled quotations of the Shanghai tael) into American units are computed prior to publication. These prices represent oil at Hankow godown, processed, plus overhead and export taxes, packing, coolie hire, profit, and other incidental charges, f. o. b. lighter, Hankow. This service has enabled American consumers to follow carefully the trends in the primary market and formulate their purchasing policy accordingly, thus saving them considerable sums annually. Prior to the inauguration of regular cabled reports, there had often been a marked spread between Honkow prices and United States domestic quotations, which has been largely eliminated since that time.

MARKETING ORGANIZATION AND METHODS

Although China has for many years been the only important and practically the sole world source of tung oil, the industry is in no sense controlled by a Government monopoly. The marketing of tung oil bears no resemblance to the monopolies formerly controlled by Great Britain in rubber, Brazil in coffee, Japan in natural camphor, and Chile in nitrates.

The organization and character of the tung-oil trade has undergone a marked change during the past 10 years. Prior to 1920 the trade was handled principally by American, British, German, French, and other foreign trading firms operating in China. These

firms, known as hong, customarily purchased tung oil through Chinese buyers or compradors, who maintained their own organization and had buying agents at the principal collecting centers, such as Wanh sien, Changteh, and Chungking. These compradors were paid periodically a retainer for their services, and in addition received a commission based on the value of their purchases.

In consideration of the growing importance of shipments of oil in bulk from primary collecting centers during the period 1923 to 1925 most of the foreign firms handling tung oil established branch offices of their own at important Upper Yangtze ports and ceased to operate through Chinese buyers. Under the old system the comprador purchased the crude oil upon arrival at Wanh sien or other centers, settled the product, consigned the clean oil to his foreign principal, and sold the residue to native dealers for the local trade. On the other hand, foreign firms buying direct in the producing areas generally purchased the crude oil and shipped it to Hankow for clarification. Extension of bulk export activities encouraged a number of the larger Chinese and Japanese dealers to engage in the tung-oil export trade, and at present it is estimated that such firms control from 25 to 35 per cent of the total foreign shipments.

TRANSPORTATION AND PACKING

There has been a progressive change in the packing and transportation methods employed in the shipment of tung oil from China, following increases in the volume of trade. Formerly casks, barrels, and tins imported into China containing other merchandise were filled with tung oil for export to foreign countries. In view of their availability (coincident with the increasing trade in petroleum products with China and the Orient) 5-gallon kerosene tins were most frequently used. These tins were split open on arrival in the United States and the oil was transferred to barrels for transportation to interior consuming points. Certain unsatisfactory features of this method of transportation led to a change to barrel packing of tung oil for export shipment. Waste from soakage into the staves was remedied to a degree by lining with waterproof paper, but during the winter months shipments arrived in a frozen state and it was often necessary to destroy the barrel and lose a portion of the contents in order to transfer the oil and convert it to a liquid state. During the World War substitution of softwood barrels in place of hardwood containers formerly used resulted in considerable loss and damage to cargo. The tung-oil trade increased markedly during the early postwar period, and tank steamers were finally adopted during that period as a solution of the transportation problem. The advent of tank-steamer transportation brought with it one outstanding difficulty—that of excessive moisture absorption by the tung-oil cargo. Steps have been taken to solve this problem, and losses and waste in tung-oil transportation have been practically reduced to a minimum. Prior to loading, the tank steamers are cleaned and inspected by competent marine surveyors at Hankow and Shanghai, and many of them are equipped with steam coils to keep winter-month oil cargo in good condition during transit.

In the United States the shipment of tung oil in tank steamers has resulted in the adoption of tank cars for inland transportation. In

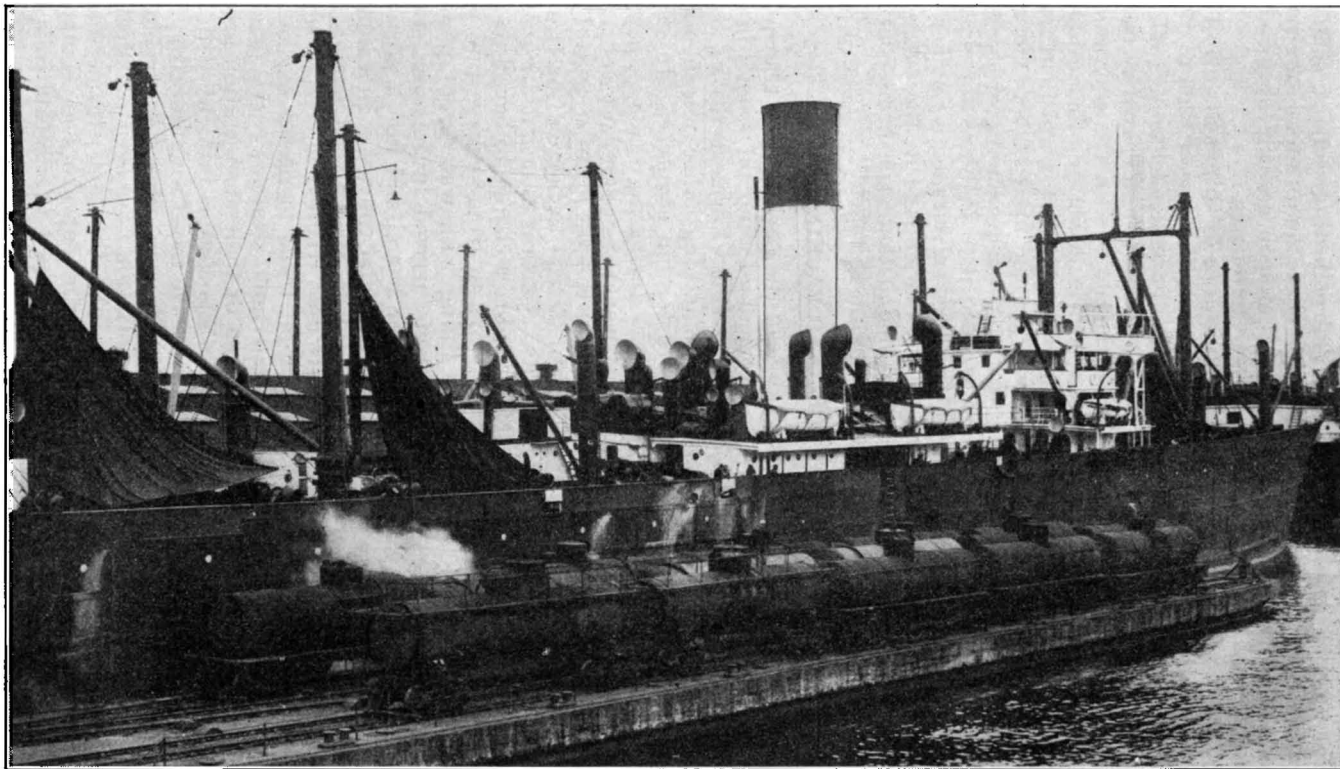


Figure 11.—Unloading tung oil from China into tank cars at New York docks

China this change has necessitated the installation of pipe lines from tung-oil storage tanks to shipside anchorage or near-by piers. In general, therefore, there has been a marked improvement in transportation and packing methods, reducing the cost of transportation from Chinese shipping centers and insuring to American and other foreign consumers arrival of the oil in better condition.

The great diversity of weights employed in different sections of the tung-oil producing area in China, the inaccuracies of weighing devices, and the problem of converting and checking losses in transportation or after refining were for many years problems to American and foreign tung-oil brokers and consumers. To-day tung-oil shipments are generally estimated at Hankow and Shanghai by calibration, as well as by actual weighing. Automatic scales of the hopper type have been adopted by a number of Chinese tung-oil shippers, and more accurate computation of tung-oil cargoes is now possible.

ADULTERATION A HANDICAP

Lack of uniform quality has been one of the important factors restricting the more general acceptance of tung oil in the United States and other foreign markets. It has been acknowledged both by past and by present experience that the quality and characteristics of individual shipments vary somewhat in accordance with their origin, influenced to a degree by differences in climatic conditions, soil, treatment of seeds, method of pressing, and age and species of tree. Of greater consequence in affecting the quality of Chinese tung oil is the practice of adulteration. A number of factors have encouraged the practice of adulterating tung oil, either directly or indirectly, outstanding among which are (1) complex organization of the trade, (2) restricted knowledge of tung-oil properties, (3) political disturbances and irregular supplies of the oil, (4) active foreign demand, and (5) high level of prices as compared with other oils.

The passage of tung oil through the hands of many intermediaries en route to the export center increased the possibilities of adulteration, while the lack of knowledge of the physical and chemical properties of the oil and the undeveloped state of analytical methods until recent years made it difficult to detect the addition of extraneous materials. Irregular arrivals of tung oil, coupled with an active foreign demand, tended to encourage such practices to meet existing orders. Substances generally employed in adulteration are vegetable or mineral oils which are priced lower than the tung oil. The most common of these adulterants are cottonseed, sesameseed, rapeseed, teaseed, peanut, soyabean, and poppyseed oils, and certain mineral oils have been detected in some export shipments.

The Chinese Nationalist Government has realized that these practices of their merchants and brokers have done much to restrict the oversea reception of certain Chinese export products and have taken active steps to remedy this evil. In the latter months of 1928 the Ministry of Labor and Commerce began the organization of a National Export Products Inspection Bureau, designed primarily to standardize and inspect export shipments of cotton, wood oil, and animal products. The Testing Bureau Office at Shanghai was estab-

lished in March, 1929, and that at Hankow in May, 1929. No tung-oil testing was undertaken at Shanghai at the outset, although actual testing at Hankow was initiated on November 6, 1929. It was later found advisable (in March, 1930) to include tung oil among the products inspected at Shanghai in order to catch shipments not docked at Hankow. During 1931 an additional Government testing station was established at Wanhhsien. This compulsory inspection of tung oil has unquestionably had the effect of raising the general quality of export shipments and has tended to create a greater confidence among foreign buyers and consumers. The Chinese regulations for the testing of tung oil are given on page 101. The standards established are designed to improve the color, appearance, and quality of the oil. Official Chinese inspection offices not only check the activities of those in the habit of adulterating tung oil, but are also conducting research work to improve the average quality of the oil produced in China and are expected ultimately to recommend progressive changes in methods of production and distribution.

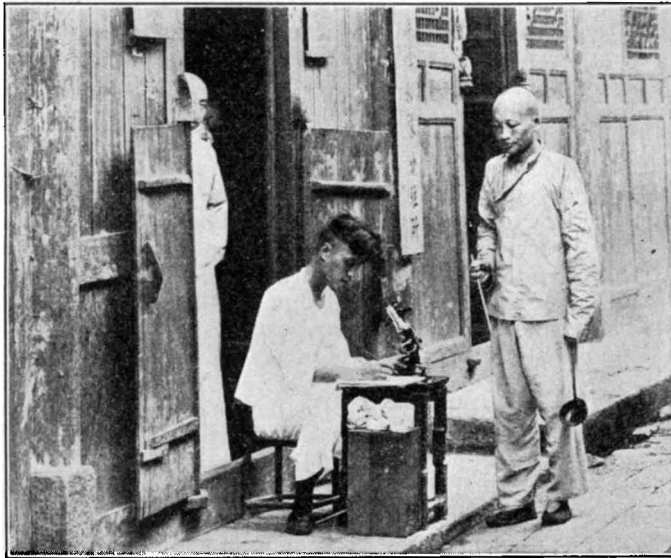


Figure 12.—Testing tung oil for purity. Practice prior to establishment of Government testing stations

EFFECT OF INTERNAL TAXATION

The complexity and variance of internal taxation have been for many decades a burden to the tung-oil trade and a problem to tung-oil exporters. Because of the general political disorganization of the former Chinese Empire, provincial authorities were allowed to levy burdensome taxes on business operating within their jurisdictions and on trade passing through their territories, the levies varying in general with the revenue requirements of the particular Province. Banditry has from time to time been prevalent in the Upper Yangtze Provinces, and the police and military authorities were often needed to provide, at a price, escort ships or other protection

to tung-oil shipments passing through their territory. The long haul from the producing areas and the transit through a number of Provinces often entailed the payment of transit dues and other taxes to each of the provincial tax-collecting agencies. The Chinese Nationalist Government has realized that these provincial levies are a detriment to trade and has been attempting by various means to reorganize national and provincial revenues and taxing systems in a more equitable manner. To this end, on January 1, 1931, likin and other internal taxes on trade were officially abolished.

Conditions relative to internal taxation have improved somewhat in recent years, but a conception of the various taxes effective on tung oil may be gained from the following levies on shipments from Chungking to Hankow during the early months of 1930:

	Equivalent in Shanghai taels (per picul)
Export duty, 0.30 haikwan taels per picul	0.321
Export surtax, 0.15 haikwan taels per picul	.161
Local surtax, 0.15 haikwan taels per picul	.161
Payable at Chungking	.643
Likin, transit, and municipal and provincial road and highway construction levies (total)	.289
Import surtax at Hankow (3½ per cent of value)	.114
Oil-testing fee	.070
Total estimated taxation	1.258

EXPORT DUTY ON TUNG OIL

The first recognized export tariff of China became effective in 1858, including among its rates an export duty of 0.30 haikwan taels per picul on tung oil. According to official records, no changes were made in that duty until 1929, when, in view of revenue needs, an export surtax of one-half of the existing export duty was levied. Ostensibly with a view to the adjustment of duties to changed conditions of the trade, an upper revision of the export duty on tung oil was made in the Chinese tariff act which became effective June 1, 1931, the new duty of 1.60 haikwan taels per picul being considerably higher than the previous levy plus the surtax.

FOREIGN MARKETS FOR TUNG OIL

Tung oil is now one of the prominent industrial raw materials entering into world trade. Practical demonstrations of the valuable properties of the oil, increasing knowledge of proper technical procedure, and the adaptation of the product to new industrial applications in foreign markets have been largely responsible for the notable progress which has been achieved in the development of Chinese export trade in this commodity. The use of tung oil has expanded materially, but as yet world consumption has by no means reached its saturation point.

At present tung oil finds its major utility in the paint and varnish, linoleum and oilcloth, and printing-ink industries of the world. However, consumption of the oil in these established outlets has not shown the expansion which would seem to be warranted by reason of its special properties and qualifications. This lagging in the rate of consumption has been attributed principally to certain undesirable features of the tung-oil trade.

Experience has indicated clearly to industrial consumers throughout the world the business hazards associated with dependence upon a single foreign source for supplies of a basic raw material. While price-control measures or production restrictions have not been applied in the tung-oil trade, a number of other factors have contrib-

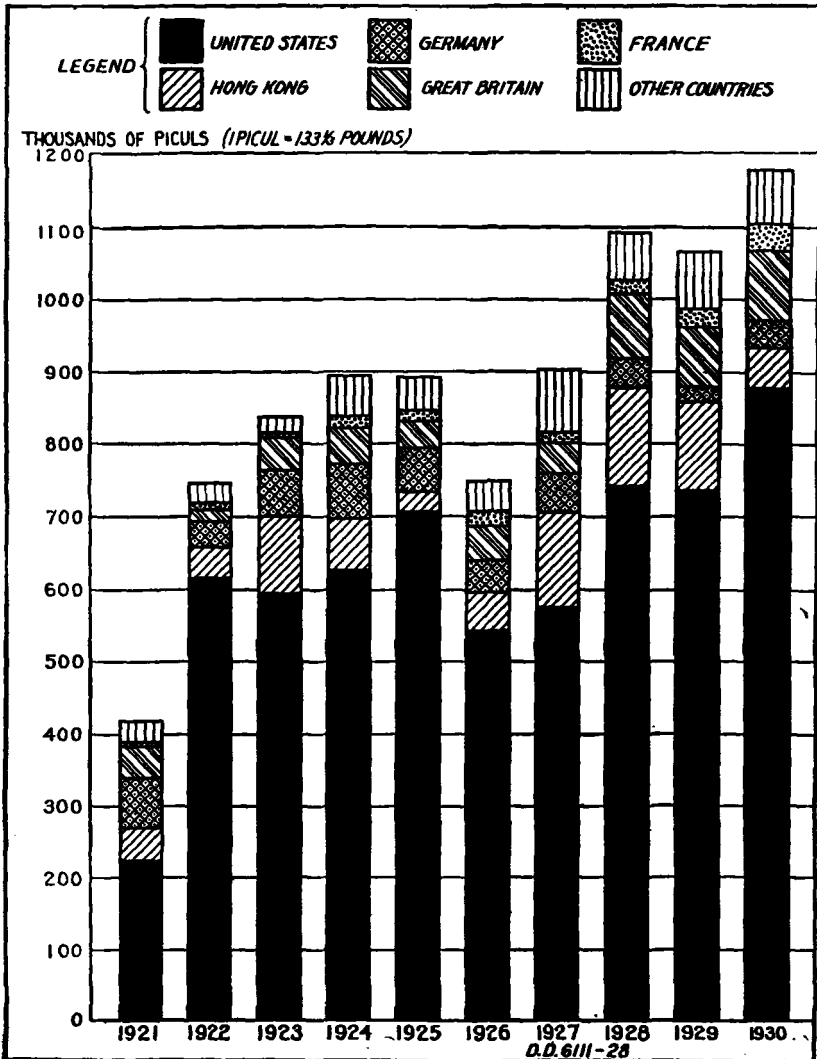


Figure 13.—Tung-oil exports from China, showing comparative standing of leading foreign outlets

uted to make trading in this commodity somewhat uncertain. Irregularity of shipments, variance in quality, and wide fluctuations in the price of the oil have deterred many manufacturers from changing their formulas to adopt this material on a large scale. The development of American production of tung oil is expected to materially increase available world supplies, stabilize trading, and stimu-

late the extended use of this commodity both in the United States and in foreign countries.

Recent progressive changes in the organization and operation of the Chinese tung-oil trade designed to stabilize the market and improve the quality of the exported oil, however, are gradually developing greater confidence among consumers and may indirectly result in material amplification of world demand. The consistently low price of the oil during the last few years is also tending to encourage more widespread consumption in foreign markets.

Oversea shipments of tung oil from China go to all parts of the world. Foreign demand is naturally predicated upon the extent of industrial development, and therefore Europe and North America are the outstanding regions in which tung oil is consumed. Except in China and Japan, there is little demand for this drying oil in the Far East, although the development of paint and varnish and other industries in India and Australia may result in substantial markets in those countries in future years.

EXPORT SHIPMENTS, 1926 TO 1930

The following table shows the distribution of Chinese exports of tung oil during the years 1926 to 1930.

EXPORTS OF TUNG OIL FROM CHINA, 1926-1930

[In piculs; 1 picul=133¼ pounds]

Countries of destination	1926	1927	1928	1929	1930
United States.....	540,013	572,316	740,239	735,244	874,006
Great Britain.....	48,657	44,680	99,868	84,035	94,229
Germany.....	46,004	54,400	42,884	23,943	36,071
France.....	20,036	13,689	17,206	25,044	30,796
Netherlands.....	15,566	57,003	25,824	33,139	36,808
Japan.....	7,678	6,575	7,965	19,754	10,777
Italy.....	3,780	5,501	5,633	6,773	6,334
Denmark.....	2,412	3,391	5,501	4,846	7,203
Belgium.....	3,321	3,440	2,271	2,950	3,620
Sweden.....	1,507	2,408	2,777	2,604	2,940
Norway.....	1,361	1,905	2,667	2,020	5,010
Hong Kong.....	53,533	133,683	138,364	124,868	55,427
Straits Settlements.....	885	788	1,112	799	360
Other countries.....	3,431	915	1,908	3,631	3,674
Total.....	748,184	901,294	1,094,290	1,069,650	1,167,255

IMPORTANT CONSUMING COUNTRIES

Chinese export statistics present only a general picture of the requirements of individual foreign markets. Oil passing through Hong Kong to other markets is all credited to that British Colony rather than to the countries of ultimate destination. Bulk transportation of the oil in tank steamers, now well established in the tung-oil trade, has made necessary the establishment of important warehouse and transshipment centers in Europe, where the cargo may be subdivided and packed in barrels and drums for shipment to individual purchasers. A large share of European consignments are now initially handled at Hamburg, Liverpool, Rotterdam, and several other concentration centers, whence they are widely distributed to Continental consumers from the Arctic to the Mediterranean. A certain proportion of the tung-oil shipments destined

to the United States is reexported to Canada and other neighboring countries.

CONSUMPTION OF TUNG OIL IN EUROPE

The European markets at present absorb only about 15 to 20 per cent of the total Chinese export of tung oil, compared with over 70 per cent received by the United States. Extensive flaxseed cultivation in Europe and the strong position of linseed crushing in Great Britain, the Netherlands, and Germany, have for many years afforded an ample supply of linseed oil for European consumption. Established utility and spot availability have enabled linseed oil to maintain its preeminent position in the European drying-oil market and have made the entry of an imported oil difficult, regardless of its qualifications. Technical difficulties in the application of tung oil restricted its more general use in European industries until recent years. The conservatism of British and Continental manufacturers has made them reluctant to change established formulas and has thus tended to make progress in the utilization of tung oil rather slow.

GERMANY

Germany is at present the leading European outlet for tung oil, by reason of the extensive manufacture in that country of paints, varnishes, linoleum, oilcloth, and other products in which the oil is employed. Chinese export statistics do not indicate the prominent position of Germany as a consuming market, since a considerable share of the tung oil purchased enters that country via the Netherlands, Great Britain, and France. Statistics showing imports of tung oil into Germany during the past five years are given in the following table.

GERMAN IMPORTS OF TUNG OIL, 1926-1930

Year	Pounds	Value in dollars
1926.....	10,381,360	1,513,442
1927.....	13,381,060	2,390,731
1928.....	14,657,720	2,341,143
1929.....	14,705,680	2,266,223
1930.....	13,632,520	1,795,905

The German paint and varnish industry is the principal consuming channel for this oil, taking over 80 per cent of the total imports annually. The following figures recently released by the German Federal Statistical Office show the quantity and value of tung oil used in paint and varnish manufacture, as compared with the consumption of linseed oil and other vegetable oils.

CONSUMPTION OF VEGETABLE OILS IN THE GERMAN PAINT AND VARNISH INDUSTRY IN 1928

Item	Pounds	Value in dollars
Tung oil.....	12,181,400	1,977,040
Raw linseed oil.....	16,159,000	1,220,943
Refined linseed oil.....	22,125,400	1,639,898
Other vegetable oils.....	8,762,600	614,368
Total.....	59,228,400	5,452,249

As may be noted from the foregoing figures, tung oil consumed in the German paint and varnish industry represents over 20 per cent by quantity and 36 per cent by value of the total vegetable-oil requirements of that industry.

UNITED KINGDOM

The United Kingdom is the second largest market for tung oil in Europe, present consumption requirements being estimated roughly at 9,000,000 to 10,000,000 pounds annually. Tung oil is not shown separately in the British trade returns but is included under the classification "Other vegetable oils, unrefined, not elsewhere specified." British customs authorities claim that receipts from China and Hong Kong under this heading consist mainly of tung oil, and therefore represent roughly tung-oil imports into the United Kingdom. These figures are shown in the table below in comparison with exports to Great Britain from China.

BRITISH RECEIPTS OF TUNG OIL FROM CHINA, 1926-1930

Year	Chinese exports of tung oil to the United Kingdom	Estimated imports of tung oil into United Kingdom
	Pounds	Pounds
1926.....	6,471,380	5,845,400
1927.....	5,931,440	7,231,400
1928.....	11,176,660	8,665,800
1929.....	13,261,450	10,489,600
1930.....	12,532,460	8,582,200

Some conception of the extent of British transit trade in this raw material may be gained from a comparison of the figures presented. Reexports are destined mainly to countries of continental Europe, and to a lesser degree to certain of the British Dominions and Colonies, although in 1927 and 1928 a shortage of available oil in Great Britain resulted in substantial purchases for home consumption from Netherland stocks.

The British paint and varnish, linoleum, and certain other tung oil consuming industries are well developed and should afford an expanding field of utility for this imported raw material. At present the volume of linseed oil consumed in paint and varnish manufacture in the United Kingdom is more than twelve times as great as that of tung oil. However, Dr. L. A. Jordan, of the Research Association of British Paint, Colour, and Varnish Manufacturers, stated recently that the use of tung oil in that British industry would probably increase more than twofold during the coming decade.

FRANCE

France ranks third in Europe as a market for tung oil. Trade estimates indicate that the French consumption ranges from 3,500,000 to 4,000,000 pounds annually. Havre is the principal French port at which tung oil is received, followed in importance by Marseille and Dunkerque. A substantial share of the oil imported by French consumers is purchased through agents in the major European trad-

ing ports. Paint and varnish manufacture, one of the oldest industries in France, has shown material progress since the World War, both in extent of production and in technical methods employed. The French paint and varnish industry now supplies approximately 90 per cent of the domestic requirements for such products. Purchases of tung oil should continue to expand in volume in proportion to the steady development of that industry. Well-developed specialty industries consuming considerable quantities of tung-oil varnish will also indirectly influence purchases of this raw material.

NETHERLANDS

Definite figures are not available showing receipts and consumption of tung oil in the Netherlands. Netherland imports of "Other vegetable oils" from China are, for the purposes of this study, employed as estimates of tung-oil importation, since they consist mainly of tung oil. These approximations for the five years 1926 to 1930, converted to a common unit, are contrasted below with exports of tung oil to the Netherlands from China.

NETHERLAND RECEIPTS OF TUNG OIL FROM CHINA, 1926-1930

Year	Chinese exports of tung oil to the Netherlands	Estimated imports of tung oil into the Netherlands
	<i>Pounds</i>	<i>Pounds</i>
1926.....	2,070,300	562,840
1927.....	7,661,200	732,670
1928.....	3,434,600	990,600
1929.....	4,407,620	1,252,600
1930.....	4,895,470	1,200,540

The difference between these two sets of figures indicates roughly the volume of tung-oil transshipments handled at ports in the Netherlands.

The Netherland paint and varnish industry is fairly extensive, but its use of tung oil has been restricted by a strong preference for linseed oil. In 1923 the consumption of tung oil in that industry was estimated at about 500,000 pounds. At present it is stated that over 1,000,000 pounds are employed in paint and varnish manufacture in the Netherlands.

DENMARK

Denmark consumes a larger quantity of tung oil than is indicated by Chinese export statistics. Official statistics report the consumption of 1,298,000 pounds of tung oil in the Danish paint industry in 1929, contrasted with 1,034,000 pounds in 1928. The Danish production of varnishes increased in value from \$781,400 in 1926 to nearly \$1,000,000 in 1929. While formerly a boiled-linseed-oil product was employed almost exclusively in varnish applications, tung-oil varnishes are now being manufactured in increasing quantity for both general and specialized varnish uses.

ITALY

Chinese exports of tung oil to Italy have shown a gradual expansion during the past five years, in line with the progress made by the

Italian paint and varnish industry. Sales to Belgium have been well maintained and a more active demand is noticeable in Norway and Sweden.

CONSUMPTION OF TUNG OIL IN JAPAN

So-called Japanese tung or wood oil is derived from *Aleurites cordata*, a tree of the same family as *fordii* and *montana*, which yield the Chinese product. The oil from *Aleurites cordata* is not strictly competitive with tung oil and, since production in Japan is relatively small, the product has not assumed a significant position in world trade in drying oils. The annual production of this oil in Japan declined steadily from a peak of nearly 2,500,000 pounds in 1917 to about 800,000 pounds in 1925. Although production has increased slightly during recent years, the yearly output has rarely exceeded 1,000,000 pounds, most of which is consumed in the home market. Local production does not amply supply Japanese requirements, and considerable tung oil is imported each year from China.

The consumption of tung oil in Japanese industries is roughly estimated at 2,000,000 to 3,000,000 pounds annually, employed principally in the manufacture of varnishes, in the waterproofing of paper umbrellas, and in the lacquer and lacquer-ware industries. The Japanese paint and varnish industry has progressed considerably during the past decade, and annual production of varnishes is now estimated at nearly 4,000,000 pounds.

UNITED STATES THE LEADING WORLD MARKET FOR TUNG OIL

The United States is the outstanding world consumer of tung oil to-day, a position which is due to the rapid growth of the American paint and varnish industry and other outlets for this product. As a result of active research efforts, greater progress has been made in the United States than in other countries in the adaptation and extension of the uses of tung oil. This pronounced inclination of United States industries to utilize high-grade materials, as exemplified in tung-oil consumption, has contributed materially to the establishment and maintenance of a quality reputation for American paint products both at home and abroad.

EARLY DEVELOPMENTS

The early history of the tung-oil import trade may shed some light on the pioneer consumption of tung oil in the United States and the problems which were overcome to bring that product to its present important position as an industrial raw material. Although shipments of tung oil from China to European consuming centers began in the early sixteenth century, the first importation of this oil into the United States was recorded in 1869, when 138,635 pounds, valued at \$53,641, were brought in by clipper ships trading with the Orient. At that time little was known about the uses of the oil, and opinion among scientists differed concerning the value of the commodity as an ingredient in the manufacture of varnish. Moreover, cheap and abundant supplies of linseed oil and natural gums were obtainable, and manufacturers were reluctant to change their formulas. In 1899 the United States consulate at Hankow submitted a report describ-

ing the value and use of tung oil in China which aroused greater interest in the product and caused the importation of larger quantities. In order to learn more about the foreign industry and to obtain reliable information regarding supply and market conditions, a questionnaire was prepared by the consulate at Hankow in 1903 and forwarded to Americans residing in the Provinces of Central China, to native merchants, and exporters of the oil.

The information obtained by the consulate, assembled in report form and published by the Department of Commerce and Labor on March 15, 1905, was one of the first important contributions to literature on this subject. Expanding trade interest and an increasing volume of shipments to the United States prompted Commercial Attaché Julean Arnold to collect additional information on Chinese production and trade in tung oil which provided basic data for preparation by the Bureau of Foreign and Domestic Commerce of a detailed bulletin on this subject in 1923.¹ These early official publications led to a more general knowledge of tung oil among American industries, and thus indirectly stimulated the United States import trade in this product.

In addition many contributions to the development of trade in this commodity have been made by representatives of both the Department of Commerce and the Department of State. Valuable assistance has been rendered in the establishment of branch buying offices in China and in the selection of reliable purchasing agents. Studies of transportation and warehouse problems in the tung-oil trade have been made, and the adjustment of numerous shipping claims has been facilitated. A monthly tung-oil cable service initiated in 1925 enabled American consumers to follow current conditions in the Hankow market affecting oil supplies and price quotations, and thereby helped to stabilize the trade.

IMPORTS OF TUNG OIL INTO THE UNITED STATES

The United States import trade in tung oil has had a remarkable and steadily maintained growth during the past decade. The following table shows the volume and value of such importations.

TUNG OIL IMPORTED INTO THE UNITED STATES, 1921-1931

Year	Pounds	Value	Year	Pounds	Value
1921.....	27, 248, 887	\$2, 469, 659	1927.....	89, 650, 411	\$11, 809, 583
1922.....	79, 089, 293	7, 891, 251	1928.....	107, 356, 971	13, 419, 029
1923.....	87, 291, 675	13, 397, 000	1929.....	119, 677, 718	14, 972, 084
1924.....	81, 587, 854	11, 091, 776	1930.....	126, 322, 599	12, 487, 352
1925.....	101, 553, 519	11, 385, 848	1931.....	79, 311, 155	4, 425, 922
1926.....	83, 003, 774	9, 148, 090			

Although it has been mentioned previously that China is at present the only foreign source of tung oil in commercial quantities, yet it may be puzzling to analyze statistics of imports of this commodity by countries of origin and note fairly large shipments from

¹ China Wood Oil, by William M. Taylor. Bureau of Foreign and Domestic Commerce, Miscellaneous Series No. 125. This publication is now out of print and can no longer be obtained from the Superintendent of Documents, but it may be found in libraries in the larger cities.

other countries. This peculiar trade feature has been particularly evident during 1923, 1924, and 1927, when considerable price fluctuation and speculation occurred as a result of uncertain supplies from China. United Kingdom, Germany, and Japan have carried on some brokerage and transshipment trade in this product with the United States in the past, but since 1928 supplies received in this country have almost in their entirety originated in China. Hong Kong (geographically a part of China but politically a colony of Great Britain) occupies the peculiar position of an important shipping outlet for Chinese tung oil. The marked changes in the volume of tung oil received from Hong Kong indicate to a degree the particular periods during which, because of a difficult outlet through Hankow, Yangtze Valley oil supplies were diverted to supplement Kwangsi Province production exported through that port. The following table shows volume of tung-oil imports received from China, Hong Kong, and other countries from 1923 to 1931.

UNITED STATES IMPORTS OF TUNG OIL, BY COUNTRIES OF ORIGIN, 1923-1931

Year	China	Hong Kong	Other countries
	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>
1923	77,930,932	7,047,000	2,313,443
1924	76,447,232	4,083,126	1,047,496
1925	98,125,282	2,595,044	883,193
1926	80,332,821	2,462,001	208,952
1927	75,043,427	12,769,724	1,837,260
1928	97,783,436	10,675,043	763,292
1929	109,549,217	9,976,409	152,092
1930	121,138,804	5,076,005	107,790
1931	75,632,777	3,599,378	79,000

New York, San Francisco, and Seattle are the principal United States ports which figure in the tung-oil import trade. Receipts at each of these ports have varied somewhat from year to year, and during the past 11-year period a marked change has taken place in their relative standing as ports of entry for this commodity. During 1929 and 1930 the port of New York handled approximately 45 per cent of the total imports into the United States, as compared with from 20 to 30 per cent in previous years. San Francisco has been gradually gaining in importance as a west-coast receiving center; while Seattle, which was formerly port of entry for over 50 per cent of the trade, now handles less than 25 per cent of the total imports.

UNITED STATES BROKERAGE AND REEXPORT TRADE IN TUNG OIL

The well-established tung-oil trading organization which has been developed in the United States as a result of the large domestic requirements and the expansion of bulk shipment by tank steamer from Hankow direct to Atlantic and Pacific ports has encouraged the development of a substantial brokerage or reexport trade in tung oil with neighboring countries. Of the total United States import trade in tung oil, from 3 to 5 per cent is reexported annually, principally to Canada. The following table shows the growth of the transshipment trade in tung oil during the period 1922 to 1930.

UNITED STATES REEXPORT TRADE IN TUNG OIL, 1922-1930

Year	Quantity	Value	Year	Quantity	Value
	<i>Pounds</i>			<i>Pounds</i>	
1922.....	2,703,495	\$342,830	1927.....	5,286,565	\$743,131
1923.....	3,463,058	625,410	1928.....	6,185,537	839,027
1924.....	2,213,035	334,809	1929.....	6,191,007	825,660
1925.....	2,566,815	337,104	1930.....	6,258,981	661,646
1926.....	3,578,662	645,843			

The rapid expansion of American branch-plant development in Canada in the field of paints and varnishes may account in a measure for the growth of this trade with that market. The reexport trade with Canada increased steadily from 1,986,700 pounds in 1924 to 5,732,036 pounds in 1929, although it fell off to 5,123,000 pounds in 1930. The trade with Germany has been of importance only during the past five years and declined gradually from 1,091,500 pounds in 1926 to 156,800 pounds in 1930. Reexport shipments to the United Kingdom and the Netherlands have fluctuated considerably, ranging from 30,000 to 300,000 pounds during the period 1926 to 1930. Cuba and Argentina have developed during the past two years as fair reexport markets for tung oil, each taking over 200,000 pounds from the United States in 1930, compared with less than 80,000 pounds in 1929. Russia, France, Union of South Africa, and Australia have taken occasional shipments.

CONSUMPTION OF TUNG OIL IN THE UNITED STATES

Statistics showing the production, consumption, and importation of fats and oils (tung oil being included), in the United States are compiled by the Census Bureau of the Department of Commerce. Figures showing the annual consumption of tung oil in the United States and factory warehouse stocks at the end of each calendar year are shown in the following table.

CONSUMPTION AND STOCKS OF TUNG OIL IN THE UNITED STATES, 1920-1930

Year	Annual consumption	Factory and warehouse stocks as of Dec. 31	Year	Annual consumption	Factory and warehouse stocks as of Dec. 31
	<i>Pounds</i>	<i>Pounds</i>		<i>Pounds</i>	<i>Pounds</i>
1920.....	46,381,235	20,484,902	1926.....	84,984,456	18,090,135
1921.....	35,965,800	9,291,675	1927.....	82,335,688	17,785,312
1922.....	62,855,998	17,983,724	1928.....	95,092,806	25,454,461
1923.....	72,333,664	19,321,526	1929.....	97,473,834	29,411,191
1924.....	70,529,915	20,660,914	1930.....	87,092,168	49,894,404
1925.....	87,881,315	32,943,278			

It may be noted by comparing consumption statistics with import figures that the latter do not constitute a very reliable index of United States requirements in tung oil, as market and other conditions often cause the importation of quantities far in excess of current industrial needs. Although 1930 was the peak import year for tung oil, actual consumption of the oil by American industry fell off as compared with 1929, in keeping with the general retrenchment of

business during that period. The upward trend of stocks from 1921 to 1925, the decline in 1926, and gradual accumulation up to a new high in 1930 reflect changes in the volume of consumption in relation to import purchases.

Quarterly consumption trends.—Quarterly statistics of tung-oil consumption in the United States serve to show the regular demand and rather even utility of the oil throughout the year. These figures afford a marked contrast with the widely fluctuating quarterly receipts from China. For example, consumption in individual 3-month periods during the past seven years has varied from 17,500,000 pounds to 26,700,000 pounds, whereas quarterly imports have ranged from a low 3-month total of 10,300,000 pounds to a high of 35,950,000 pounds. No well-defined seasonal trend is noted in imports of tung oil, principally because of the irregularity of arrivals from China. The outstanding characteristic of tung-oil consumption is the consistently large demand during the quarter from April to June. In general stocks held have rarely exceeded the normal average quarterly requirements of industry and have followed fairly closely the general trend of imports. In 1930, however, a slump in consumer demand coupled with increasing imports resulted in an extraordinary rise in stocks. Quarterly factory consumption, imports, and stocks are presented in graphical form in Figure 14.

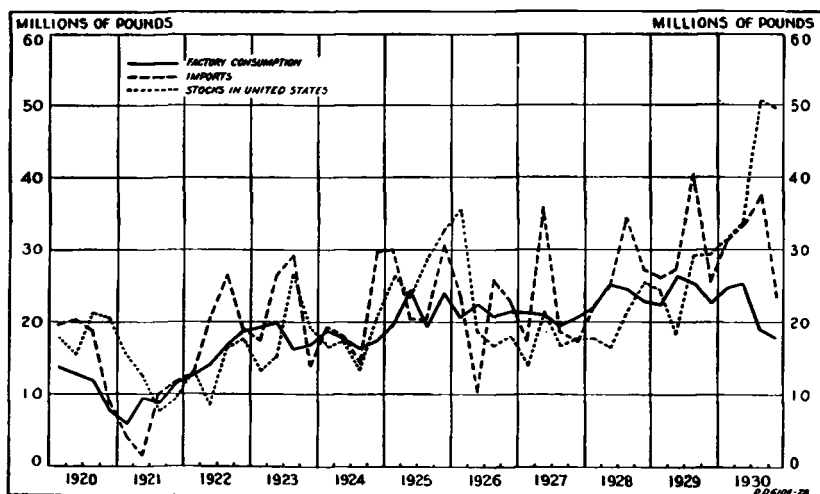


Figure 14.—Quarterly indices of factors in domestic tung-oil consumption

Consumption factors and price.—Price is customarily one of the major considerations affecting consumption of raw materials. This factor is of primary significance in determining the profitable limits of raw-material utility within the well-defined spheres of application established by its properties. However, the valuable properties and special usefulness of tung oil in the manufacture of quality products has, to a degree at least, offset the direct effect on consumption of price increases. On the other hand, the downward trend of prices in recent years has tended to amplify the demand for tung oil and has resulted in a more general interest in this product among indus-

trial consumers. The range of domestic prices, showing the monthly high and low quotations per pound during the years 1922 to 1931 for tung oil in barrels at New York, are given in the following table. In general, prices per pound for tung oil in tanks on the Pacific coast are from 1 to 2 cents per pound lower than the New York market quotations.

QUOTATIONS ON THE AMERICAN MARKET FOR CHINESE TUNG OIL, MONTHLY HIGH AND LOW, 1922-1931

[Price per pound for oil in barrels, New York]

Year	1922		1923		1924		1925		1926	
	High	Low	High	Low	High	Low	High	Low	High	Low
January.....	\$0.14½	\$0.12¾	\$0.18½	\$0.13½	\$0.21¾	\$0.19½	\$0.16	\$0.14¾	\$0.13½	\$0.13
February.....	.16	.13½	.19	.18	.19½	.17¾	.14¾	.13	.13½	.12¾
March.....	.15	.14	.35	.18½	.18½	.17	.14	.13	.12¾	.12¾
April.....	.14½	.13	.40	.28	.17	.14¾	.13¾	.13	.12¾	.11½
May.....	.15	.13½	.40	.25½	.15	.14	.13	.12½	.12	.11½
June.....	.14½	.13½	.29½	.25½	.14	.12½	.14½	.12½	.15½	.15
July.....	.14	.12½	.27	.23	.15	.11½	.14	.13½	.16½	.15
August.....	.13½	.12½	.24½	.22	.15	.14	.13½	.13	.18	.17
September.....	.13½	.12½	.22½	.21½	.15½	.14½	.13½	.13½	.19	.17½
October.....	.13	.12½	.23½	.21½	.16½	.15	.13½	.13½	.17½	.16
November.....	.13	.12½	.22	.21	.16	.15½	.13½	.13½	.16½	.15
December.....	.14	.12½	.21½	.21½	.16	.15½	.13½	.13	.15½	.13½

Year	1927		1928		1929		1930		1931	
	High	Low	High	Low	High	Low	High	Low	High	Low
January.....	\$0.15½	\$0.13½	\$0.18	\$0.15	\$0.16	\$0.14¾	\$0.12½	\$0.11½	\$0.07½	\$0.07
February.....	.18½	.17	.17½	.16½	.14½	.14¾	.12½	.11½	.07	.06¾
March.....	.27	.22	.15	.14	.14½	.14	.12	.11½	.07	.06½
April.....	.35	.30	.16	.14	.14½	.14¾	.11½	.11	.07½	.07
May.....	.29	.19½	.15	.14½	.14½	.14¾	.11	.10½	.07	.06½
June.....	.21	.20	.15½	.15	.14½	.14¾	.10½	.09½	.07½	.06½
July.....	.20½	.17	.15½	.15	.14½	.14	.09½	.09	.07½	.07
August.....	.18	.17	.17	.15	.14½	.14	.09½	.09	.06½	.06¾
September.....	.18	.16	.15	.14½	.16	.14½	.09	.08½	.07½	.06¾
October.....	.16	.15	.15½	.15½	.15½	.15	.08½	.07½		
November.....	.15½	.15½	.15	.14½	.15½	.14½	.07	.07		
December.....	.15½	.14½	.14½	.14½	.14½	.13½	.07	.07		

Source: American Paint Journal.

CONSUMPTION OF TUNG OIL IN CANADA

The total quantity of tung oil consumed in Canada and the percentage supplied by the United States reexport trade may be judged roughly from statistics showing annual consumption of this oil in the Canadian paint and varnish industry. The use of tung oil in that industry has shown fairly consistent progress, 2,178,800 pounds being employed in paint and varnish manufacture in Canada in 1919, 5,004,500 pounds in 1924, 8,540,000 pounds in 1928, 10,618,400 pounds in 1929, and 6,378,300 pounds in 1930. The United States is apparently supplying an increasing percentage of Canadian tung-oil requirements through reexport channels.

TUNG OIL IN INDUSTRY

The unique properties and characteristics of tung oil give it a position in industry unrivaled by other drying oils and raw materials.

PHYSICAL PROPERTIES

As found in its natural state in the cells of the seeds, the oil is practically colorless and neutral in reaction. The Chinese oil of commerce, however, is a yellow liquid at ordinary temperatures, containing up to 7 per cent free acid and possessing a strong earthy odor. These changes in the physical properties of the oil may be attributed principally to crude methods of handling the nuts and producing the oil in China. Many improvements have been noted in the physical constants of tung oil produced by machine expression in the United States. A lighter color has been attained, a lower acidity has been recorded, and the odor of the oil has been appreciably lessened.

Tung oil has a high viscosity and will gradually thicken and gelatinize upon constant exposure to light. The valuable distinctive features of this oil are the manner and rapidity with which it dries and the impermeability of the film which it forms upon drying.

Tung oil dries largely by polymerization, a spontaneous molecular transformation. This oil in heat-treated or varnish form produces a hard, quick-drying, waterproof film, highly resistant to acids and alkalies, and possessing in combination with phenolic resins marked dielectric properties. It is rarely used in a raw state, since the drying action of the oil is considerably accelerated and a much superior film is obtained by cooking or heat treatment. In the raw state, frosted or opaque wrinkly film is formed.

Careful formulation of heat treatment or cooking practices was necessary in the preparation of tung oil because of its strong tendency to gelatinize into a worthless insoluble mass at temperatures above 450° F. Strict observation of heat applied and the prevention or retarding of solidification by the addition of rosin, lead compounds, and certain other substances have made possible successful heat treatment of the oil.

CHEMICAL COMPOSITION

The chemical composition of tung oil differs somewhat from that of most other drying oils. The principal constituent of the oil is a glyceride of a fatty acid known as elæostearic acid, which appears, according to present knowledge, to be isomeric with linolenic acid. Elæostearic acid is formed by three double bonds, each connected by single bonds. This closely conjugated structure of the acid is said to be largely responsible for the polymerization action and rapid-drying characteristics of the oil. Tung oil also contains about 10

per cent of the glycerides of oleic acid and from 2 to 3 per cent of the glycerides of saturated fatty acids (mainly palmitic and stearic).

Conclusive work on the chemistry of tung oil has up to the present time been rather limited. However, the development of a more extended knowledge of the structure and composition through research may be instrumental in improving present methods of application and may thus serve to amplify the usefulness of the oil to American industries. Research agencies are now attempting to isolate the active drying principle or beta-fraction of elæostearic acid, which may eventually bring into commerce a high-powered derivative capable of exceeding in effectiveness the oil as a whole.

PRESENT AND POTENTIAL USES

Material standards can not adequately measure the value of tung oil to industry. This commodity has gained particular prominence as a constituent of coating and finishing products such as varnishes and enamels. Its distinctive properties have contributed greatly to the quality and efficiency of these products in their diversified fields of application. It has aided especially in the improvement of industrial finishes employed in the construction, furniture, automotive, electrical, textile, lithographic printing, specialized ink, household appliance, and specialty industries. The exceptional quick-drying properties of tung oil have definitely assisted in speeding up industrial-finish operations and maintenance and repair jobs, enabling a saving of many thousands of dollars in those fields annually. The preservative and waterproof qualities of the oil have naturally added to the durability of finished products upon which it is employed, curtailing recoating and replacement costs. Although the outstanding merit of tung oil is well known by industrialists, the American public in general is not familiar with the widespread employment and value of this product. Many extravagant claims have been made by experimenters as well as promoters relative to the present and potential uses of tung oil. The following paragraphs, therefore, are intended to point out the character and extent of present applications of tung oil and the possible new spheres of use indicated by research experiments.

PAINT AND VARNISH

The American paint and varnish industry has risen to a high plane of scientific accomplishment and public benefit largely through its active development and employment of new raw materials and processes. The selection and formulation of the best possible products for specific industrial applications constitute an outstanding achievement of that industry, one in which tung oil has played an important part, particularly in the field of varnish manufacture.

A number of difficulties were encountered in the early use of tung oil, chief of which was its tendency to gelatinize at relatively low temperatures; but as knowledge of the product developed, satisfactory methods of handling were evolved. Tung oil was initially used in varnish manufacture as a flux for some of the hard gums which were difficult to fuse without loss of color. Later, its employment with rosin was found to produce a varnish having better resistant

and waterproof properties than the then standard type derived from linseed oil and fossil gums. Grinding liquids prepared from a tung-oil rosin base were gradually developed for use in enamel manufacture.

The demand which has developed so rapidly since 1914 for quick-drying finishes to speed up industrial operations and commercial maintenance jobs has resulted in a greatly amplified use of tung oil in such products. Tung oil is now recognized as an essential and outstanding constituent of industrial varnishes both for general and specialized uses—a growing industry in the United States—and is gaining in importance as a component of rapid-drying vehicles for enamels and certain types of paints. The discovery and application of new synthetic gums in varnish formulation have added greatly to the efficiency and popularity of tung oil for those purposes.

NEW INDUSTRIAL VARNISH OUTLETS DEVELOPING

The wide field of application of varnishes is well known. In the household they find extensive use in surfacing floors, woodwork, and wood trim. Varnish finishes are still employed in motor coach and bus work and for certain applications on automobiles and railway rolling stock. In the furniture and piano field, however, lacquers have made a rather strong intrusion.

The recession in the former standard applications for old-type varnishes has resulted in the more marked development of specialized industrial varnishes and the consequent more widespread use of tung oil as a varnish ingredient, since it appears to be better qualified than other drying oils to meet these new requirements in industrial coating and finishing. Tinware coating compositions, lithographic varnishes, insulating varnishes, and airplane finishes are but a few of the new applications in which the use of tung oil has proved particularly desirable. Those enumerated above are discussed in following paragraphs as representative of this relatively new but promising field of tung-oil utilization.

Tinware and lithographic printing.—The more extensive use of tin containers for canned foodstuffs, cigarettes, spices, medicines, paints, and a great diversity of other products, as well as the growth of business in bottle caps, advertising plates and signs, has materially expanded the field of lithographic printing. Varnish is applied in some instances direct to the metal base, as well as on labels or as a finish coat after the inscription or design has been applied. High-grade varnishes having particular adhesion to metals are required. Such varnishes provide a satisfactory protective film for the label, and produce a very durable film capable of withstanding the stamping and molding process employed in the final preparation of the container. Tung-oil varnishes are finding increasing use in lithographic printing, and a gradual expansion of consumption in this industry is anticipated.

Insulating varnishes.—Tung oil is employed to a considerable extent in the electrical industry, particularly as an ingredient in insulating varnishes. Trade comment indicates that tung-oil varnishes are well adapted to electrical use. They are more resistant to water and oil and produce a firmer and faster drying film than do

most other materials. The fact that tung oil dries largely by polymerization rather than by oxidation has in this use proved particularly advantageous, since in the presence of a high-tension electrical field certain materials tend to disintegrate slowly and lose their insulating properties, whereas tung-oil compositions are not readily affected.

Insulating varnishes for coil treatment, for coating cloth and other fibrous materials, for finishing insulated wire and metallic surfaces, and for use in many other electrical applications are made with tung oil as the principal drying-oil constituent. Varnished tapes of various kinds for use in high-tension cables and in the winding of transformers are surfaced mainly with specially prepared asphaltic tung-oil varnishes. The manufacture and use of tung-oil insulating varnishes by the American electrical industry have shown marked progress during the past decade, and present indications point to a continued growth in the extent and diversity of tung-oil applications in the manufacture of electrical materials.

Aeronautical applications.—The aeronautical industry requires high-quality finishes to preserve and protect all parts of planes which are subject to continual exposure to the elements. These surfacing compositions are used not only on newly built planes but also for periodic maintenance of the more than 10,000 registered airplanes on civil duty as well as several thousand additional ones utilized in test flying and in Army and Navy flight service. For the protection of interior and exterior wood surfaces and glue joints, paint has proved too heavy for practical use, while ordinary varnishes and shellacs have not been sufficiently water-tight. Spar varnishes prepared with tung oil are recommended in United States Navy specifications and are in wide use for finishing hulls, wooden parts, and wing surfaces of planes for both governmental and commercial service. Tung oil is also employed in various vehicles used in the manufacture of enamels for airplane interior trim. Preliminary reports by airplane-finish manufacturers indicate that this oil may be adopted as an important constituent of new products being developed for coating metal aircraft parts.

ENAMELS, PAINTS, AND LACQUERS

High-grade enamels are prepared by incorporating suitable pigments with quick-drying tung-oil varnishes. Although the rapid-drying enamels were originally designed for and appeared to be most adapted to amateur painting, their use in industrial channels is gradually expanding.

Both tung oil and tung-oil varnishes have received attention as potential vehicles for oil paints for both exterior and interior use. Tung-oil paints have been exposed in Florida¹ and it is reported that satisfactory and promising results have been obtained. Tung oil has been found by manufacturers of aluminum paint to be the most satisfactory general-purpose vehicle for their products. The elasticity of tung-oil vehicles and their imperviousness to water, in conjunction with the waterproof nature of aluminum powder provide the qualities of a stable and serviceable paint of high protective value for exterior application which has stood up well on wood,

¹ See Proceedings, Scientific Section, American Paint and Varnish Association, 1931.

iron, millboard, asbestos cement sheet, and a number of other bases. Tung oil in combination with gilsonite, asphalt, and other substances, is finding increasing employment in preservative compositions for ironwork, metal roofs, storage tanks, and sidings.

The invasion of nitrocellulose lacquers into consumption channels formerly employing quick-drying varnishes and enamels has tended to curtail indirectly the use of tung oil in those industries. However, certain uses of tung oil have developed in conjunction with lacquers. In metal finishing, such as in automobile body work, tung oil has found some utility as a plasticizer for nitrocellulose lacquers, particularly in heat-treated form, in priming coats on copper and aluminum. It is claimed that tung oil adds greater adhesiveness to the lacquer on those materials. Tung oil has also found utility in varnishes used as wood-stain vehicles for employment with lacquer coatings on furniture and other articles of wood.

One of the best-known uses of tung oil in China is in combination with the sap of *Rhus vernicifera*, known as the varnish tree, in the preparation of Chinese lacquers. This product is poisonous to the skin of human beings unaccustomed to handling it, and therefore its manufacture or use in the United States has not developed to any extent.

PAINT DRIERS AND SYNTHETIC RESINS

Tung oil is also used in the formulation of paint driers, which are usually metallic soaps of drying-oil organic acids, employed primarily as catalysts to speed up the drying time of paint and varnish products. In the manufacture of tungate driers it is claimed that cobalt is the most efficient and satisfactory metallic base, followed in order by iron, manganese, copper, chromium, lead and zinc. Tung oil has also been employed recently in the formulation of certain synthetic resins.

USE IN COMBINATION WITH TEXTILES

Protective coating.—The principal application of tung oil in textile manufacture is in the branch of that industry concerned with protective coating of textiles. Its use is outstanding in the preparation and finishing of linoleum, felt-base floor covering, oilcloth, and artificial leather. According to available statistics, the consumption of other drying oils in linoleum and oilcloth manufacture seems to have expanded more rapidly than that of tung oil. The following table shows the relative use of drying oils in this industry in 1929 as compared with reported consumption in 1925.

USE OF DRYING OILS IN OILCLOTH AND LINOLEUM MANUFACTURE, 1925 AND 1929

[Thousands of pounds]

Kind	1925	1929
Linseed oil.....	93,340	112,855
Menhaden oil.....	9,154	10,141
Tung oil.....	5,630	5,963
Soyabean oil.....	2,154	3,229

The difference in ratio of expansion may be due to the greater utilization by linoleum and oilcloth manufacturers of tung oil in varnish form, purchased as such, since a much greater increase in the use of tung oil and tung-oil products has been indicated by individual manufacturers in the trade.

Tung oil is generally heat-treated prior to use in the protective-coating industry. Generally speaking, the oil is not employed as an impregnating fluid but as a vehicle for other coating materials, principally in blends with other oils and in specially prepared coating varnishes. The blending of tung oil with linseed results in a product very suitable for application in this industry. Tung oil has advantageously replaced linseed oil only in printed felt-base composition finishes.

Waterproofing.—Tung oil has been used for many years in the Orient as a waterproofing agent for textiles. Its application in the United States for that purpose, however, is believed not to have advanced as rapidly as the product merits. The consumption of tung oil in combination with textiles, excluding its use in linoleum and oilcloth manufacture, amounted to only 17,000 pounds in 1929. The field of waterproofed textiles includes bagging and packing cloth, wagon and horse covers, tents, awnings, tarpaulins, raincoats, hunters' and sportsmen's equipment, as well as seat covers and automobile tops. The introduction of rubberized cloth and chemically treated textiles has tended to restrict somewhat the use of tung oil in waterproofing textiles, and time and fashion have changed to some degree the character of the demand for these products. Nevertheless, the industry is becoming increasingly alert to new materials, and tung oil may find more extended application for such purposes. It is at present utilized in the manufacture of light-weight cloth for raincoats, and very recently in the preparation of patent waterproof wall coatings.

Brake linings.—Several concerns now manufacturing automobile brake linings are using tung oil with asbestos and cotton. After these components are molded they are baked at 500° F. This baking process sets the oil. A fairly substantial outlet for tung oil may be expected in this field.

PRINTING AND DRAWING INKS

The Bureau of the Census reports that 437,000 pounds of tung oil were consumed in the American printing-ink industry in 1929. The oil is not customarily employed in the manufacture of general-purpose printing inks, but is used in heat-treated form in specialized applications, such as overprinting and gold-bronze printing.

It has been reported that in China both tung oil and its oil cake are burned to a soot to produce a finely divided carbon used in making waterproof India inks. No definite information is available to indicate the extent of the manufacture of waterproof drawing ink from tung oil in China, and American manufacturers of drawing ink apparently do not utilize this material. However, some research efforts in this connection might be worth while.

USE IN SOAP MANUFACTURE LIMITED

A survey of raw materials utilized in the American soap industry conducted by the Fats and Oils Division of the United States De-

partment of Agriculture (the findings of which were published in 1919) shows that 118,000 pounds of tung oil were consumed for soap making in 1916 and 115,000 pounds in 1917. However, according to a compilation prepared by the Bureau of the Census, tung oil was not consumed by soap manufacturers in 1929. The use of tung oil during the war period was largely predicated upon the difficulty of obtaining adequate supplies of other soap oils.

A leading American soap authority thinks it unlikely that tung oil will ever have an important place among raw materials for soap manufacture. Tung oil is not a particularly satisfactory soap ingredient from a technological standpoint because of its excessive drying qualities, which result in the production of a soft, mushy soap, subject in many instances to rancidity. In addition, the price factor is of chief importance, as more satisfactory oils can be obtained at less cost. The use of tung oil would probably be limited to special soaps for leather dressing or automobile cleaning; but for such soaps corn oil and soybean oil are equally suitable. Tung oil is utilized in the manufacture of so-called metallic soaps, discussed under the heading of paint driers. Because of the reputed small possibility of extended use of tung oil in soap manufacture, little attention has been given to this oil by the soap trade.

EXPERIMENTAL USE IN WOOD PRESERVATIVES

Tung oil has been employed experimentally in the United States in conjunction with creosote oil as a wood preservative, designed for use against termites. Leading authorities on wood preservation maintain that it is not likely that there is any preservative property in the tung tree or in tung oil that would have practical value in protecting wood from either insects or fungi. In view of the relatively high cost of tung oil in comparison with materials commonly in use for those purposes, it appears that if such a principle were present it would have to be exceedingly toxic in order to be economically employed. The sealing and waterproofing properties of the oil might be of some value, but would not constitute a permanent protection against termite attack.

Tung-oil varnishes mixed with barytes, according to the Forest Products Laboratory, rank very high as moisture retardants and as end coatings for logs and lumber to reduce waste from checking, splitting, stain, or decay, but they have had little use for that purpose as yet.

PROMISING FIELD AS FISH-NET PRESERVATIVE

The United States Bureau of Fisheries in an investigation of fish-net preservatives during 1931 conducted tests employing tung oil in varying combinations with copper oleate, coal tar, and toxic dye. Cotton nettings treated with tung-oil compounds maintained and in some instances increased their original tensile strength in periods of exposure in fresh, salt, and brackish waters for the duration of the tests lasting six months. On the other hand, nets treated with many other preservatives, some of which are in present use, manifested a tendency to weaken gradually upon exposure. While all features of its application are not desirable, tung oil has shown sufficient promise in this field to warrant further investigation by both private and governmental agencies.

REPUTED MEDICINAL PROPERTIES

Certain authorities have claimed that tung oil possesses active medicinal principles and might therefore be useful in the manufacture of remedies or medicinal preparations. Reports indicate that the oil has been used in China as an ingredient of a native medicine employed in the treatment of wounds. It is also regarded there as a specific against skin diseases, especially the itch, and is sometimes employed to bring back warmth to the body in cases of asphyxia.

It is known that tung oil has a strongly purgative action when taken internally, and therefore it might have a laxative or emetic value. It was believed that there might be present in tung oil some enzymelike product capable of exerting an anthelmintic action on hogs or other animals. It has also been considered possible that tung-oil products might be useful for their deworming action on poultry. Preliminary tests conducted by the Zoological Division of the United States Department of Agriculture, however, did not give satisfactory results for tung oil administered in doses of various strengths to swine as an anthelmintic for large intestinal roundworms and ascarids.

INSECTICIDAL PROPERTIES

It has been suggested that the comparative freedom of tung trees from insect attack in the United States might be attributed to the presence of a valuable insecticidal principle in the tree proper or in the derivative oil. However, this apparent immunity in the United States is largely coincidental, since it is reported that in China the trees are attacked by certain species of caterpillars, scale insects, and leaf hoppers.

The Chinese attribute insecticidal properties to certain products of the tung tree. It is reported that in China the tung seeds are used for killing rats. In the Provinces of Hupeh and Szechwan, in China, tung oil has been applied to the ground to moisten the roots of plants and thus preserve them from insect attack. Many Chinese planters have been known to soak various types of seed in this oil prior to sowing, so that they will not be eaten by white ants before germination. M. Dabry de Thiersaut, in 1878, advocated the use of tung oil in France to fight the ravages caused by phylloxera, but experiments conducted along this line at Montpellier in that year did not confirm the results which were expected.

It is not definitely known whether an active insecticidal or medicinal property is present or might be profitably extracted from tung oil or other tung-tree products, but such might be problems worthy of further study and investigation.

BOAT CALKING AND PRESERVATION

The oldest and most important use of the oil in China is in combination with pomace residue, lime, and bamboo shavings to produce a material employed extensively in the calking of the great number of junks and other small craft found on the inland waters of the country. In addition to imparting a bright luster to the woodwork of the ship, the product serves to preserve and waterproof the treated surfaces. The Chinese claim also that it is superior to

tar for protecting the sides of vessels against the attacks and incrustations of mollusks, but tests in the United States have not shown that it could be economically used for that purpose.

WATERPROOFING CONCRETE

Tung oil has been considered in the past as a possible waterproofing agent for concrete. In experiments with concrete waterproofing compound conducted during 1931 at the Bureau of Standards, tung oil proved to be the best transparent coating tested. Several concrete waterproofing compositions containing tung oil are now being marketed commercially. Tung-oil varnish is also recommended as a sealer before waterproofing cement with certain types of paint products.

MISCELLANEOUS USES

Tung oil is employed in the gaskets on steam pipes, pumps, and engines, and as a waterproofing material for cartridge shells. In the interior of China the oil is used as an illuminant, but its application for this purpose is not particularly satisfactory, since it provides a very smoky, sooty flame. It has been reported that tung oil is used in leather dressings, but in the United States it is believed that it finds only a limited employment in special varnishes used for patent-leather finishes, or for the protection of leather belting, and in a few waterproofing applications on leather. Certain uses of tung oil on paper have been the subject of considerable investigation in recent months, and tests of this material in the production of a moisture-proof and grease-proof coating for bagging and carton stock are being made.

Although comprehensive research investigation may establish the suitability of tung oil for many new uses, careful investigation of the economic feasibility of these projected applications is suggested.

INTERCHANGEABILITY OF DRYING OILS

Increasing intercommodity competition in recent years characterizing markets for finished products has made proper selection and use of raw materials more essential to successful manufacturing activity. As a result of research investigations, new properties and applications of standard materials have been discovered and many satisfactory substitute raw materials of both synthetic and natural origin have been brought to light. These developments have accentuated the desire in industry for a more thorough knowledge of the characteristics, uses, sources, and market conditions of available crude products. The question is often asked whether tung oil definitely competes with or is to be preferred to other drying oils. This question can be adequately answered only by a comparative study of the entire field of drying oils as it is known at the present time.

In general, the interchangeability of various oils and fats in industrial usage is dependent upon the following material and economic factors: (1) Their related physical or chemical properties; (2) their fairly equal adaptability for similar purposes; (3) their availability from either domestic or foreign sources; and (4) their relative prices.

Commercial fats and oils are essentially combinations of glycerin with certain fatty acids, and, based upon their physical and chemical properties, they find specific uses either as drying oils, food oils, or soap oils. In the producing areas, however, certain uses may prevail for the oils because of the large available supply and the absence of or difficulty of obtaining a better qualified product.

Vegetable oils grouped according to their siccative tendencies are classified generally as drying, semidrying, and nondrying oils. Tung oil has been included under the drying oils, although its method of drying differs from that of most of the other oils of the group. The drying reaction of all these materials, however, is principally accounted for by the presence in the oils of a high percentage of certain unsaturated fatty acids.

COMPARATIVE INDICES OF DRYING OILS

Comparative technical indices of 13 of the best-known drying oils are presented in the following table. As the results obtained by various authorities differ somewhat, a range of values is given in most cases. The specific gravity indices of the oils indicate the comparative weights. According to leading technicians the refractive index of oils increases in accordance with the degree of unsaturation, and this factor is therefore indirectly an index of the relative drying power of an oil. The iodine number of an oil is the percentage, by weight, of iodine absorbed, and is the usual basis for comparisons of the drying power of oils.

COMPARATIVE INDICES OF DRYING OILS

Name	Specific gravity at 15° C.	Refractive index at 25° C.	Iodine number
Principal drying oils:			
Tung.....	0.9390-0.9450	1.5160-1.5240	¹ 163-170
Linseed.....	.9300-.9400	1.4792-1.4820	173-201
Soybean.....	.9220-.9340	1.4720-1.4750	124-143
Menhaden.....	.9260-.9360	1.4787	139-180
Perilla.....	.9280-.9340	² 1.4810-1.4830	185-206
Less important drying oils:			
Lumbang.....	.9200-.9370	1.4750	140-164
Oiticica.....	.9520-.9660	1.4900-1.5094	³ 140-184
Hempseed.....	.9250-.9330	⁴ 1.4770-1.4796	140-166
Walnut.....	.9250-.9270	⁴ 1.4708-1.4725	140-158
Safflower.....	.9230-.9280	1.4766-1.4772	140-150
Rubber-seed.....	.9225-.9316	1.4733	133-146
Lallemantia.....	.9336-.9340		162-167
N'gart.....	.9354-.9410	² 1.4810-1.4830	195-204

¹ The iodine number of tung oil represents the iodine absorbed by only two of the three unsaturated bonds in the oil and consequently is not a reliable index of the high relative drying power of the oil.

² Taken at 20° C.

³ Varies widely according to method used, but is known to be very low as an index of the drying power of the oil.

⁴ Taken at 15° C.

As will be observed in the foregoing table, tung oil has the second highest specific gravity and the highest refractive index, and it has been known to show an iodine number between 220 and 235 with methods causing the more complete absorption of iodine.

Although there are a large number of vegetable oils and a few fish oils which are known to possess drying or waterproofing properties, there are only a few of commercial importance at present.

Many of the drying oils are not available in sufficient quantities to make their general industrial application feasible, or they possess certain constituents or peculiar properties which affect their proper film-forming ability. The cost of producing certain of them would be prohibitive, considering their low yield of oil or the necessarily complex method of their expression or extraction. Therefore, in view of an abundant supply of linseed oil, tung oil, soybean oil, perilla oil, and menhaden oil at low prices for commercial use, the development of other less-known drying oils would be difficult under present conditions. Nevertheless, a summary discussion of the drying oils mentioned in the foregoing table in their relation to tung oil is presented for the guidance of industrial consumers and technical research staffs.

LINSEED OIL

Linseed oil is obtained from the seeds of the flax plant (*Linum usitatissimum*, Linn.). The seed variety of flax plant is grown in many countries of the world, but the seed crop is usually exported to certain industrial consuming countries for the expressing of the oil. The leading flaxseed producing countries of the world are Argentina, Russia, India, United States, and Canada, while the principal countries producing linseed oil are the United States, Russia, Great Britain, Germany, the Netherlands, Canada, and France. The total world production of flaxseed in recent years has ranged from 120,000,000 to 150,000,000 bushels, while the world output of linseed oil is estimated at 1,600,000,000 to 1,800,000,000 pounds. The United States is the outstanding producer of linseed oil, accounting for from 40 to 45 per cent of the world total. A statistical comparison of domestic linseed-oil production and import for the years from 1921 to 1931 is presented in the following table:

UNITED STATES LINSEED OIL PRODUCTION AND IMPORTS, 1921-1931

Year	Domestic production	Imports for consumption	Year	Domestic production	Imports for consumption
	<i>Pounds</i>	<i>Pounds</i>		<i>Pounds</i>	<i>Pounds</i>
1921.....	482,917,742	60,088,500	1927.....	776,714,498	6,360,283
1922.....	456,514,418	143,878,323	1928.....	751,444,531	173,918
1923.....	653,563,870	42,729,260	1929.....	763,576,494	9,135,118
1924.....	705,585,985	13,576,828	1930.....	516,326,277	2,572,021
1925.....	763,822,379	13,906,301	1931.....	530,735,372	224,853
1926.....	720,109,940	9,609,896			

Source: Production statistics, Bureau of the Census, Department of Commerce; import figures, Foreign Commerce and Navigation of the United States.

Linseed oil is the oldest known drying oil employed in the Western Hemisphere. Its long-established use as a paint vehicle and its prestige in rather widespread applications have rendered difficult its replacement by other drying oils. The demonstration of the better adaptability of tung oil, perilla oil, and certain other products for specific uses has resulted in some inroads into the linseed-oil market, but a general replacement of linseed oil is not conceivable under present conditions.

The variety of products and processes in which linseed oil is employed include the following: Paints, varnishes, enamels, lacquers,

stains, roof cements, putties and primers, linoleum and oilcloth, soft soaps, printing and lithographic inks, linoleate driers, patent and enameled leathers, wood preservatives, furniture polishes, carron-oil preparations, boiled oil, core oils, tempering steels, photography, plastic compositions, liniments, artificial rubber, coating silk threads, laxative and protective emollient in medicine.

SOYBEAN OIL

This oil is derived from the seeds of *Soya hispida* and some 20 or more other varieties of this species indigenous to China, Manchuria, Chosen, Japan, and Indo-China. The development of Manchuria as a source of soybean products has been outstanding during the past decade, that region now having a greater soybean crop than all other countries of the world combined. Manchurian production in 1930 was estimated at 193,000,000 bushels, of which nearly 57,000,000 bushels were exported, principally to European markets and Japan. Soybean-oil expression is one of the major industrial activities of Manchuria. The oil is utilized locally to some extent and the remainder is exported to industrial consumers in Europe and in small quantities to the United States.

There has been manifested in recent years the beginning of what appears to be a marked change in the soybean products trade. Commercial production of soybeans has proved successful in the United States, and commercial plantings of this crop in other countries are contemplated. The development of soybean crushing in Europe and America has resulted in increased shipments of soybeans from producing areas in the Far East and a material reduction in exports of the oil. In the face of these new competitive conditions the Manchurian soybean oil-milling industry, which in 1929 consisted of 92 mills, capitalized in total at nearly \$16,000,000, has curtailed production and is declining somewhat in importance.

The production of soybeans in the United States gradually increased from 7,459,000 bushels in 1927 to 14,917,000 bushels in 1931, and a larger percentage of the crop is moving into commercial channels each year. Production of soybean oil in the United States has increased steadily during the past decade, while imports, which in general have shown considerable fluctuation during the period, are now manifesting a general downward tendency. Comparative figures showing domestic soybean-oil production and imports for the years 1921 to 1931 are given in the following table.

UNITED STATES PRODUCTION AND IMPORTATION OF SOYBEAN OIL, 1921-1931

Year	Domestic production		Imports for consumption	Year	Domestic production		Imports for consumption
	Crude	Refined			Crude	Refined	
	<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>		<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>
1921-----		5,656,166	16,711,060	1927-----	3,067,670	5,681,408	11,515,027
1922-----	751,108	3,217,796	13,633,956	1928-----	4,715,908	7,440,573	12,587,150
1923-----	1,404,035	2,567,769	33,221,548	1929-----	11,008,743	7,831,283	16,317,173
1924-----	950,437	1,797,065	11,209,970	1930-----	14,387,460	6,629,215	8,348,352
1925-----	2,519,938		15,904,711	1931-----	39,149,653	23,889,995	3,878,727
1926-----	2,645,514	7,253,250	26,369,854				

Source: Production figures, Bureau of the Census; import figures, Foreign Commerce and Navigation of the United States.

Soybean oil is employed in the Orient in the manufacture of foodstuffs, soap, varnish, printing inks, paints, candles, and waterproof goods, and for lighting and lubricating. In western countries the oil, through chemical treatment and special refinement, is used in the manufacture of lard substitutes, margarine, and salad oils. It is also used in the manufacture of linoleum, rubber substitutes, core binder, and in certain types of paint products.

MENHADEN OIL

The menhaden from which the oil is obtained is found along the entire Atlantic seaboard from Maine to Florida. Although other species of menhaden occur in the Gulf of Mexico, along the South American coast, and on the west coast of Africa, the industry of extracting the oil and fish meal has developed to an appreciable extent only in the United States. The catch of menhaden and the production of manhaden oil has been gradually declining in recent years, as may be judged by the following statistics compiled by the Bureau of Fisheries of the Department of Commerce.

MENHADEN CATCH AND PRODUCTION OF OIL IN THE UNITED STATES, 1921-1930

Year	Menhaden catch employed in by-products extraction	Production of oil		Year	Menhaden catch employed in by-products extraction	Production of oil	
		Quantity	Value			Quantity	Value
	<i>Pounds</i>	<i>Pounds</i>			<i>Pounds</i>	<i>Pounds</i>	
1921.....	618,924,500	46,953,750	\$1,719,900	1927.....	351,728,760	29,678,025	\$1,716,500
1922.....	747,470,400	53,270,062	2,904,830	1928.....	324,370,200	26,891,768	1,455,375
1923.....	666,174,873	55,960,238	3,316,275	1929.....	396,217,800	23,785,513	1,381,815
1925.....	476,524,000	45,173,250	3,001,100	1930.....	366,727,800	23,934,488	648,955

Menhaden oil is used for currying leather, in the preparation of chamois skins, for tempering steel, for making soap, and in combination with vegetable drying oils in exterior paints, printing inks, and insecticide emulsions. Sulphonated menhaden and other fish oils are employed chiefly in the textile and leather industries. It is suggested as a possible ingredient for the manufacture of linoleum and has been used as a rubber substitute and in making solutions for waterproofing. When the price of linseed oil is high, menhaden oil is used to a considerable extent as a substitute.

Pilchard, sardine, and herring oils are gaining in importance as drying oils of marine origin and may gradually supersede menhaden oil in its present sphere of usefulness.

PERILLA OIL

Perilla oil is obtained from the seeds of *Perilla ocymoides*, Linn., a plant indigenous to China, Japan, and southeastern Asia. Prior to the World War this oil was practically unknown in Europe and America, but the restricted supply and high price of linseed oil resulted in its entry into world trade and in investigations of its properties and potential applications. The oil is used in India and China for food purposes, but in Japan finds extensive use in lacquer

mixtures, in waterproofing and finishing paper umbrellas, lanterns, and artificial leather, and in the manufacture of printer's ink and paints and varnishes.

Present commercial supplies of the oil are derived principally from Japan and Kwantung. Attempts to cultivate the plant in the United States both by official and by private interests have, in general, been unsuccessful. Tests were conducted in 25 States. The crop in most sections did not reach a seed-producing stage, being affected by early frosts, while in other regions difficulties were found in machine harvesting the seed crop. Imports of perilla oil into the United States showed considerable fluctuation but averaged 5,016,-360 pounds during the 5-year period 1922 to 1926. Total figures for subsequent years are shown in the following table, together with amounts received from the two principal sources.

IMPORTS OF PERILLA OIL INTO THE UNITED STATES, 1927-1931

Year	Total		From Japan		From Kwantung	
	Pounds	Value	Pounds	Value	Pounds	Value
1927.....	5,358,160	\$547,479	905,560	\$82,069	4,408,600	\$460,214
1928.....	2,010,957	214,262	1,092,117	117,187	918,840	97,075
1929.....	5,574,319	637,962	2,193,385	253,248	3,380,934	384,714
1930.....	8,837,921	884,303	7,010,071	675,845	1,827,850	208,458
1931.....	13,285,492	729,294	6,109,512	333,099	7,172,980	396,080

As imports of perilla seed are not classified separately in official statistics, it is not possible to ascertain the quantity of this oilseed entering the United States, but production of the oil from imported seed is not believed to be consequential.

Perilla oil is rarely used in its raw state as a paint vehicle, in view of a peculiar surface tension resulting in the formation of tears or breaks in the film formed. Heat-treated perilla oil dries in about two-thirds of the time of linseed oil, producing a very hard, glossy film. In this form it is particularly useful in the manufacture of high-gloss enamels, and is considered especially adapted and better than other drying oils for that purpose. Perilla oil has also shown considerable promise as an ingredient in the manufacture of lithographic varnishes.

CONSUMPTION OF DRYING OILS IN UNITED STATES INDUSTRIES

In this study of the interchangeability of other drying oils with tung oil, it should prove interesting to observe the trends in industrial consumption of the five principal drying oils employed in United States industries during the past decade. The following table presents Bureau of the Census figures showing factory consumption of linseed, tung, soybean, menhaden, and perilla oils during the years from 1921 to 1931. The consumption figures presented cover only quantities of drying oils used in manufacturing activities and do not account for such products sold direct to painters, industrial finishers, and private individuals for paint mixing and other purposes on small-scale job work. While a considerable volume of

linseed oil is sold direct to private consumers, very little tung oil, if any, is marketed outside industrial channels.

UNITED STATES INDUSTRIAL CONSUMPTION OF DRYING OILS, 1921-1931

[Thousands of pounds]

Year	Linseed oil	Tung oil	Soybean oil	Manhaden oil	Perilla oil ¹
1921.....	242,721	35,966	39,349	60,693	652
1922.....	344,363	62,856	22,172	36,136	2,208
1923.....	381,245	72,334	26,103	55,373	6,441
1924.....	381,408	70,530	16,632	34,289	3,016
1925.....	413,943	87,881	16,830	48,473	6,017
1926.....	415,113	84,984	27,211	39,920	7,401
1927.....	469,928	82,336	14,906	50,193	5,359
1928.....	524,201	95,093	19,454	51,716	2,011
1929.....	501,235	97,474	25,734	30,660	5,574
1930.....	351,335	87,092	26,529	16,289	8,838
1931.....	298,903	82,313	51,787	19,000	13,265

¹ Figures cover imports for consumption of perilla oil; no factory consumption figures available.

² Preliminary figure, subject to revision.

As will be noted in the foregoing table, linseed oil is outstanding among the drying oils employed in United States industries; tung oil ranks second, showing the same steady increases noted in the progress of consumption of linseed oil, but declining only about 10 per cent in 1930, as compared with nearly 30 per cent for linseed. In 1931 consumption of linseed oil showed a further reduction of 15 per cent, while that of tung oil diminished less than 6 per cent. Consumption of soybean oil has fluctuated considerably, but in general has shown a steady gain in volume since 1927.

Consumption of menhaden oil has varied widely during the period under review, in some degree proportional to the catch of fish and the resultant extraction of the oil. In general, however, it may be seen that consumption of this leading fish oil has declined materially since 1927 and 1928, and other fish oils are attempting to take its place in industry.

Consumption of perilla oil, as indicated by import figures, has also varied, but since 1928 has risen steadily, reaching a high peak year in 1931.

PRESENT INDUSTRIAL APPLICATIONS OF DRYING OILS

It has been indicated previously that the degree of interchangeability of oils may be determined to some degree by an analysis of the specific industries in which they find application. The principal fields of application of drying oils are confined to the paint and varnish, linoleum and oilcloth, and printing-ink industries. The following table, as compiled by the Bureau of the Census, shows the distribution of the five leading drying oils among the important industrial outlets during 1929. No later study along this line has been conducted, and the earlier statistical analyses of vegetable-oil consumption by industries covered only a few specific outlets, and are not comparable in scope with the 1929 survey.

CONSUMPTION OF DRYING OILS IN UNITED STATES INDUSTRIES IN 1929

[Thousands of pounds]

Name	Paint and varnish	Linoleum and oil-cloth	Printer's ink	Soap	Textiles	Miscellaneous industries	Total
Tung oil.....	88, 386	5, 963	437	-----	17	2, 671	97, 474
Linseed oil.....	340, 166	112, 855	23, 894	1, 916	161	23, 894	501, 235
Soybean oil.....	5, 815	3, 229	71	6, 396	267	2, 125	17, 903
Perilla oil.....	2, 573	-----	10	-----	-----	56	2, 639
Menhaden oil ¹	10, 602	10, 141	50	9, 500	-----	367	30, 660
Total (five drying oils) consumed in industry.....	447, 542	132, 188	24, 462	17, 812	445	27, 002	649, 911
Total of all animal and vegetable oils consumed in industry.....	452, 207	133, 018	24, 950	1, 618, 953	19, 100	1, 948, 947	4, 917, 175

¹ Estimated on basis of consumption distribution of all "fish oils."

Source: Bureau of the Census, Department of Commerce.

Drying oils comprised over 98 per cent of the total animal and vegetable oils required by the paint and varnish, linoleum and oil-cloth, and printing-ink industries during 1929. The relatively small employment of drying oils in soap and textile manufacture, as compared with other oils, is quite evident.

It should be understood that the consumption of oils in the same industries does not necessarily imply ready substitution or similar application within those industries. Despite a degree of interchangeability, each of the better-known drying oils has its preferred uses; in many instances its properties limit its field of application, while in other cases price may be the determining factor.

Linseed oil has a number of disadvantages, despite its general adaptability, chief of which are its yellowing tendencies and its reluctance to combine with rosin, thus necessitating the use of higher-priced resins. Because of its relatively low drying ability soybean oil is useful mainly in combinations with other drying oils. Perilla oil has certain outstanding properties which seem particularly to qualify that oil for applications in the manufacture of enamels and other products where a high surface gloss is desirable. Consumption of menhaden oil is restricted by the size of the annual fish catch and would compete only on a small scale in oil mixtures and for specialized applications. This seems equally true of other fish oils recommended for use in paint manufacture.

Tung oil appears to present the greatest promise of expansion among the commercial drying oils surveyed. In the formulation of many products in which linseed oil alone was formerly used, blends of tung oil and linseed oil are now employed. This practice, which is becoming more general, indicates that in many instances tung oil has replaced linseed oil as a supplementary material of distinctive properties. The greater recognition of the necessity and value of quick-drying finishing materials in mass-production manufacturing has stimulated interest in tung oil and has resulted in its more extensive and more satisfactory application in varnish manufacture. In this field linseed oil was formerly the predominant raw material. Tung oil has been substituted in some other cases because

it imparts to the finished product many desirable characteristics which could not be obtained with linseed oil. Research investigations are bringing to light many new uses for tung oil, and with the prospect of domestic production of a better quality of oil in commercial quantities, further expansion of consumption seems assured, which may in a measure affect present linseed oil outlets.

COMPARATIVE PRICES OF DRYING OILS

Since prices influence manufacturers in the selection of their raw materials, an analysis of the comparative price range of the leading drying oils is pertinent as an important economic consideration in the problem of interchangeability.

The price of each of the oils rarely fluctuates beyond certain limits, because of the likelihood of at least temporary replacement by other oils of the group if prices rise too high, or a loss to producers and a subsequent restriction of output if the price falls too greatly. Therefore, in addition to the natural factors affecting directly the trend of quotations, consideration must be given to the trade activity of all oils, since possibilities of substitution are tending more and more to restrict the spread in prices of the individual materials. The following table shows the comparative price range of the five principal drying oils during the years from 1921 to 1931.

COMPARATIVE ANNUAL PRICE RANGE OF COMMERCIAL DRYING OILS, 1921-1931

[All figures in cents per pound¹ at New York, in quantities specified]

Year	Tung oil in barrels		Linseed oil in car lots		Perilla oil in drums		Soybean ² oil (crude) in barrels		Menhaden oil (light pressed) in barrels	
	High	Low	High	Low	High	Low	High	Low	High	Low
1921.....	17.0	8.5	11.5	7.6	9.3	6.3	9.5	6.0	7.3	4.8
1922.....	16.0	12.3	12.3	9.0	13.5	10.5	11.3	8.8	8.8	6.0
1923.....	40.0	13.5	16.0	11.6	16.5	13.5	13.0	10.1	11.6	8.2
1924.....	21.8	11.5	15.3	12.0	14.8	13.0	13.5	11.3	9.6	7.6
1925.....	16.0	13.0	16.4	12.1	15.8	14.5	13.5	13.0	10.8	9.0
1926.....	19.0	11.1	12.3	10.2	15.3	12.0	14.0	11.8	9.6	7.7
1927.....	35.0	13.5	10.9	9.4	16.5	12.5	12.5	11.8	8.2	7.7
1928.....	18.0	14.0	10.4	9.5	18.0	12.8	12.5	12.0	8.2	8.0
1929.....	15.5	13.5	16.3	10.0	18.0	13.5	12.5	11.0	9.4	8.2
1930.....	13.3	7.0	14.4	8.8	14.0	10.0	12.0	10.0	8.9	4.9
1931.....	7.5	6.5	9.6	6.9	10.0	6.3	10.0	8.5	4.9	4.4

¹ Linseed oil quotations from 1921 to 1925, inclusive, and menhaden oil prices for entire period converted from available gallon prices, computing 7½ pounds to the gallon.

² Soybean oil quotations on the imported oil; in general, domestic oil prices are considerably lower than imported.

Sources: American Paint Journal; Oil, Paint, and Drug Reporter.

COMMERCIAL POSSIBILITIES OF LESS-KNOWN DRYING OILS

In addition to the leading drying oils of commerce there are a number of less important oils which may be developed as industrial raw materials during the coming years. Desirable qualities possessed by these products have encouraged botanical and technical research which may result in the removal of certain limitations which at present hamper the extension of their commercial use.

LUMBANG OR CANDLENUT OIL

The drying oil known as lumbang or candlenut oil is derived from two varieties of the *Aleurites* species (*Aleurites moluccana* and *Aleurites trisperma*) found principally in the Philippines, Hawaii, the Pacific Islands, India, and the West Indies. The Philippine Islands have been considered the major potential source of the oil, although development in Hawaii has been projected, and experimental plantings of the lumbang tree have been made in British Malaya and in other areas in the Far East.

The lumbang tree has flourished in the Philippines for many years, growths extending from Luzon to Mindanao and Palawan. Plantings of the tree have been encouraged by the Philippine Bureau of Forestry, and a considerable number have been set out during the past 10 years. Commercial exploitation of the nut fruit of the tree for its oil has apparently been retarded principally by the difficulties involved in collecting the nuts from scattered producing districts and securing a regular supply for expression. Modern machinery was installed by several firms to cold-press the oil during the period 1918 to 1923, with the hope of developing the industry; but the relatively high cost of collecting the nuts or securing adequate supplies in the market caused the abandonment of these operations. The Philippine production of lumbang oil in 1925 was estimated at nearly 2,000,000 pounds valued at \$150,550, obtained mainly from the Provinces of Batanges, Cavite, and Laguna. Production of lumbang oil in the Philippines has been very sporadic during the past five years and most of the limited output has been used locally.

The oil is used in paint mixing, in calking the bottoms of small boats, and for illumination in the inland districts. It is claimed that it will produce quick-drying varnishes similar to those obtained with tung oil as an ingredient. It possesses properties somewhat similar to those attributed to tung oil and, although it does not have the peculiar polymerization reactions characteristic of that oil, lumbang oil is said to form a more elastic film and is resistant to water and soap solutions. It has been suggested in the past as a possible substitute for linseed oil as a paint vehicle and for related uses.

OITICICA OIL

Oiticica oil is expressed from the nut seeds of *Licania rigida*, Benth., or *Couepia grandiflora*, a tree found in great abundance in the forests of northeastern Brazil. The largest stands of the trees are reported in the States of Ceara, Parahyba, Para, and Rio Grande do Norte. This oil has been advanced as a possible substitute for linseed and tung oils, and considerable research work has been carried on to establish definitely its characteristics and utility. A factory was built in March, 1929, at Fortaleza, Ceara, for the expression of the oil. The State authorities have rendered considerable assistance to the venture in prohibiting the cutting of the tree, in undertaking a survey to determine the stand of *Licania rigida* in Ceara, and in exempting the factory output from State export taxes. The 1930 crop of nuts was very large, and in anticipation of an expanding demand the factory purchased far in excess of immediate

needs. In July, 1931, the stock of nuts held by the Fortaleza plant was reported at 1,800 tons. Present production of oil in this factory is estimated to be over 3,000 pounds a day in operation on a 24-hour basis.

Shipments of the oil to paint and varnish manufacturers in southern Brazil have been rapidly increasing during the past few months, that domestic outlet absorbing almost all the monthly production of 80,000 pounds. Only small quantities have been shipped to foreign countries, but the development of an export trade in oiticica oil is hoped for, and trial shipments have recently been made to Germany, England, Belgium, and the United States.

It is claimed that in properties and reaction oiticica oil is very similar to tung oil, but certain differences have been noted. The polymerization product of the Brazilian oil is clearer and more transparent than that of tung oil. At ordinary temperatures the oil often appears in a pasty state and at other times in a partly solid condition. However, tests have shown that a solution of oiticica oil in commercial benzine produces a more uniform and more transparent film than that produced by tung oil.

A paint factory in Rio de Janeiro which has conducted some experiments with the oil claims that paints prepared with oiticica oil have a greater adhesion, superior resistance to erosion, better surface preservation, and better maintenance of white tones, and are especially suitable for use in a humid and tropical climate such as prevails in Brazil. The oil is in every respect still largely unknown and its industrial development is still in the experimental stage.

HEMPSEED OIL

This oil is obtained from the seed of the hemp plant (*Cannabis sativa*, Linn.), which is found both in a wild and in a cultivated state in Europe and certain portions of the Far East. The principal producers of the seed at the present time are Russia, China, and North Manchuria. Production in the Manchurian area has been estimated at about 20,000 tons of seed annually, although Russia is conceded to be the principal world producer, based on a pre-war yearly production of 320,000 to 400,000 tons of seed, and present acreage in hemp estimated at 1,750,000 to 2,000,000 acres. Imports of hempseed from all sources into the United States have averaged 4,872,000 pounds during the 5-year period 1926 to 1930.

Hempseed is utilized as a poultry and canary feed. The oil is used for food purposes, and to a considerable extent in the producing areas as an ingredient in the manufacture of soaps, paints, varnishes, and allied products. The reaction of hempseed oil in paints is fairly comparable to that of linseed, and though its drying time is somewhat slower, it is reported to have certain advantages over that oil for some purposes. Experimental cultivation of the hemp plant has indicated its adaptability to the spring-wheat belt in the United States. Certain varieties of hempseed grown in 1930 produced yields of 31 to 35 per cent of oil, which is about the normal oil content. If it should prove satisfactory as a commercial farm crop, its use as a drying oil in this country may expand

materially, provided its price is fairly well in line with that of other competitive oils.

WALNUT OIL

Walnut oil is customarily hot-pressed from the fruit of the common "English" walnut tree (*Juglans regia*, Linn.). Although walnuts are produced in many sections of the world, notably France, Italy, Rumania, United States, and China, the nut crop is marketed principally for food purposes, and in most instances only the broken and imperfect kernels are utilized for the expression of the oil. The production of walnut oil in the United States has been developing in California as a by-product of shelling plants, the output in 1928 being estimated at 500,000 pounds, with further gradual expansion of production contemplated. Imports of the oil are not separately enumerated, but are believed to be relatively small. The domestic crude walnut oil is used principally in the manufacture of soap, although certain quantities are used in the production of enamel paints. The refined oil is suitable for food purposes. Walnut oil possesses drying properties fairly comparable with those of linseed oil, and, according to certain investigators, it forms a film which does not crack on drying. The oil has been used for centuries in Europe as a paint oil and finds considerable application in the United States in the manufacture of oil colors and printing inks.

SAFFLOWER OIL

The safflower (*Carthamus tinctorius*, Linn.) bears a seed yielding an oil reputed to have excellent drying qualities. The plant has been cultivated principally in Egypt, India, and Russia for many years, and prior to the introduction of synthetic dyes was used in the production of a red natural dye. Although considerable quantities of safflower seed are produced in those countries for the expression of the oil, neither the seed nor the oil has ever occupied a significant position in the vegetable-oil trade. In India and Egypt the cold-pressed oil has been used mainly as an edible. The heat-treated oil is employed in India in the preservation and waterproofing of leather, ropes, and other materials, and, therefore, it is assumed that it possesses special properties which might make it competitive with linseed oil if it were available in sufficient quantity for commercial expression. Boiled safflower oil has been employed in India by the natives in the manufacture of Afridi-wax linoleum and has recently been used to some degree as a paint oil in that country. Experimental plantings of the safflower in our Northwestern and Middle Western States have indicated the possibilities of this plant as an oilseed crop in the United States. Technical tests have demonstrated the suitability of the oil for certain paint and enamel applications and a market for this drying oil may develop if commercial cultivation of the seed proves feasible in the United States.

RUBBER-SEED OIL

The manufacture of a drying oil from rubber seeds was not even contemplated on a commercial scale until recent years, owing to the large planting requirements in Malaya, the Netherland East Indies, Ceylon, and other rubber-producing areas. However, recent rubber

production and market conditions have turned the attention of planters to the development of uses of rubber-seed oil in industry. Investigations were made by the Department of Agriculture of the Federated Malay States, the English Imperial Institute, and a number of other interested official and private agencies. It was found that both Ceara and Para rubber seeds yield a yellow oil with an odor resembling that of linseed oil. The oil was reported to possess fairly good drying properties and had been used to a small extent as a substitute for linseed oil in the rubber districts when prices of that oil were high. Technical tests indicated that the product was somewhat inferior to linseed oil for use in the paint and varnish industry. It was claimed, however, that the oil was a suitable material for the manufacture of soft soaps and that it might find application in the preparation of rubber substitutes. The high enzyme content and the tendency of the oil to liberate free fatty acid upon standing have prevented the successful use of rubber-seed oil in paints. However, if attempts now being made in rubber-producing countries to eliminate these deterrent factors are successful, the oil may attain commercial importance in the future as a drying oil.

LALLEMANTIA OIL

Lallemantia oil is obtained from the seeds of the plant *Lallemantia iberica*, which grows wild in the Caucasus and Turkestan and is cultivated to some extent in Russia. It is employed in Persia, Syria, and other portions of the eastern Mediterranean region as an edible oil, as an illuminant, and for fuel. According to a number of investigators it is considered to have very good drying properties and has been recommended for technical application as a substitute for linseed oil in the preparation of varnishes and paints. The limited available supply of the oilseed has restricted the use of this oil, but experimental cultivation of the plant is contemplated in certain areas, and eventually it may even be found adaptable to commercial planting in the United States.

N'GART OIL

This oil is obtained from the fruits of *Plukenetia conophora*, a plant cultivated in Cameroon. The oil expressed by the natives is used locally, principally for food purposes. The taste is similar to that of linseed oil, and the exceptionally high iodine value of the product has indicated its possible use as a drying oil. It has been found that n'gart oil gelatinizes in a manner similar to tung oil, and were commercial quantities available at a comparable price, n'gart oil might find some application as a paint ingredient.

Lallemantia and n'gart oils are characteristic of a large class of promising drying oils derived from various natural materials which are not now available in sufficient quantities to warrant serious attention from industrial consumers. They are still in the experimental stage of development and as such are primarily of interest to research chemists and industrial horticultural specialists.

DOMESTIC TUNG TREE PLANTINGS

Tung oil has attained prominence as an essential raw material since the World War. Its distinctive characteristics are keenly appreciated by progressive industries, and as yet the product stands unequalled in its now well-established fields of application.

The American market, outstanding in world trade in this commodity, has keenly realized the uncertainty coincident with complete dependence upon a distant foreign source of supply. The lack of centralization of tung-oil production in China, long and hazardous transportation to export centers, political and military unrest, varying internal-tax levies, the tendency toward adulteration, and other conditions which have contributed to the speculative nature of the trade have accentuated the desire of industrial consumers to establish an independent source of supply in the United States.

INTRODUCTION INTO THE UNITED STATES

The possibilities of domestic tung-tree cultivation seem first to have been visualized by Hon. L. S. Wilcox, United States consul general at Hankow, China. He reported having sent seeds in 1902 and 1903 and again in 1904 to some person in the San Joaquin Valley of California, and that plants from the first shipment had thrived. However, the seeds had been forwarded through other persons, and later attempts by the United States Department of Agriculture to learn the name and address of this early experimenter were unavailing.

Early in 1904 a small quantity of tung seed was sent to Washington, D. C., by Consul General Wilcox, and these seeds were placed by the Department of Agriculture with several experimenters in the warmer parts of the country. A few plants were obtained and some lived for two or three years, but all eventually died. In the meantime, Doctor Fairchild, in charge of the Division of Foreign Plant Introduction, Bureau of Plant Industry, had arranged with Mr. Wilcox to purchase and forward a considerable quantity of seed from which to raise young trees for extensive testing throughout the South and on the Pacific coast.

The larger shipment of seed was received by the Bureau of Plant Industry in 1905 and was planted principally at the Plant Introduction Garden of the Division of Foreign Plant Introduction at Chico, Calif. A large number of seedling trees resulted. When the trees were 1 year old they were shipped to State experiment stations, city parks, and cemeteries, and to private individuals throughout the milder parts of the country for test plantings. Fairly large numbers of trees were set out in Alabama, at Fairhope, Robertsdale, and Batesville; in California, at Riverside, Pasadena, and Los Angeles; in Florida, at Tallahassee, McIntosh, Lutz, St. Petersburg, and Gainesville; in Georgia, at Augusta, Cairo, Thomas-

ville, Lagrange, and Donaldsonville; in Louisiana, at Pineville, Abbeville, Alexandria, and Bolivar; in Mississippi, at Biloxi, Landon, and Lucedale; in South Carolina, at Bennettsville; and in Texas, near Houston; while single trees were planted in a number of other areas.

FACTORS DETERMINING LOCATION OF PLANTINGS

These early plantings indicated that *Aleurites fordii* could probably be grown successfully only in the Southern States, where its fruit buds would not be injured by early frosts, while the montana species would be suitable primarily in more subtropical regions. The greatest interest was initially manifested in Florida, and, largely as a result of plantings and research effort in that State, the tung tree became better known in the South, and cultivation experiments became widespread throughout the entire Gulf coastal region.

It seems strange to relate that the life of this promising new industry was really begun in a Florida cemetery. Five of the first seedlings cultivated by Doctor Fairchild at Chico, Calif., were dispatched to the superintendent of a cemetery at Tallahassee, Fla., and were planted but given little attention. In the autumn of 1906 William H. Raynes, of that city, became interested in the neglected plants and was given permission to transplant them. Only one of the five trees survived, but that tree, still standing, serves as a monument to early pioneering efforts to establish the culture of the tung tree in the United States.

Stimulated by the enthusiasm of Mr. Raynes and assisted by a gift of 100 seedlings from the original tree, a neighbor, Dr. Tennent Ronalds, became interested and planted a 4-acre grove near Tallahassee in 1912. This planting, later enlarged to 40-acres, became the first bearing grove of tung trees in America. The Raynes tree at Tallahassee served not only as an important early source of seed for subsequent plantings, but in 1913 furnished a sufficient crop to make possible the first trial expression of tung oil in the United States. This experiment, conducted by a representative of the Paint Manufacturers Association of the United States, yielded 2.2 gallons of oil from the bushel of whole fruits submitted.

The results of preliminary experiments in the introduction and adaptation of the tung tree in the United States were presented to the largest consuming factors in the tung-oil trade by Doctor Fairchild in addresses before the Paint Manufacturers Association of the United States and the National Varnish Manufacturers Association, in the fall of 1912, to invite their friendly interest and cooperation in domestic tung-oil cultivation projects. These two groups were favorably impressed with the prospect of a domestic industry, because of the dependence of member manufacturers on China for supplies of this important varnish oil. Although consumption of tung oil was constantly increasing, the uncertainty of shipments, resultant speculation, and wide price fluctuations, as well as the variance in quality of the imported oil, caused considerable uneasiness among consumers.

Therefore, during the fall seasons of 1912 and the four years following, Henry A. Gardner, representing the two associations mentioned, visited the southern Gulf States to investigate the commer-

cial possibilities of tung-tree cultivation in the South. A favorable report on this survey, completed in 1921, resulted in more active efforts on the part of these associations to stimulate plantings in the United States.

In 1923 the American Tung Oil Corporation was formed as a subsidiary of the American Paint & Varnish Association, primarily to demonstrate the possibilities of producing tung oil in the United States. This company, financed exclusively by leading domestic paint and varnish manufacturers, was designed and operated as a nonprofit-making venture, to encourage the growth of tung trees on a commercial scale in this country, and thereby ultimately to develop a domestic supply of the oil. Assistance to prospective planters was to be rendered through the development and dissemination of accurate information relative to proper planting practice, based upon experience of the corporation in experimental planting. About 200 acres were initially acquired at Gainesville, Fla., upon which tung trees were planted, under widely varying conditions, for observation. The establishment of this experimental grove jointly by individuals representative of the largest market outlet for the oil marked the beginning of a period of real progress in tung-tree planting in the United States.

Tung oil expressed from seed yields of domestic plantings examined by Doctor Gardner and the research staff of the association even in early experiments was reported to be of better color and quality than oil procured from China. These and many subsequent studies both by official and by private agencies pointed to a future market for domestic tung oil, predicated naturally upon the development and success of extensive commercial plantings and the economical harvesting of the nuts and expression of the oil, and its sale at competitive prices.

ECONOMIC CONSIDERATIONS IN THE SOUTH

The planting of tung trees has been suggested as a solution of many of the difficult agricultural problems of the South. The outstanding position of cotton in the economic life of many of the Southern States has resulted in marked fluctuations in individual and general business prosperity following closely trends in the cotton market. It is contended that the addition of a new industrial crop will assist in diversifying agricultural activity and thus may bring a more balanced prosperity to that region.

Timber exploitation in the South far exceeds replacement by afforestation and in certain States is rapidly exhausting this important natural resource. The large and increasing acreage of cut-over timberland represents, at present, a considerable economic loss to the South. Therefore the problem of a profitable utilization of these waste lands has been of material concern to lumber companies and owners of such property in the Gulf coastal region. Tung nuts have been visualized as a potential crop for some such areas, and lumber firms have played an important part in the encouragement and development of tung-tree plantings in Mississippi, Louisiana, and Texas. If the tung tree satisfactorily solves this problem, benefits will accrue not only to property owners, workers, and all classes deriving income or sustenance from the land, but to county and State treasuries as well, in the form of increased tax returns.

Extensive planting of tung trees may lead to the development of a substantial milling industry, a movement in keeping with the trend toward industrialization now quite evident in the Southern States. Since tung oil, turpentine, and rosin are essential raw materials in paint and varnish manufacture, certain leaders in the paint industry, as well as tung-tree planters, have visualized the commercial production of tung oil in conjunction with the already well-developed naval-stores industry of the South as an incentive to the extension of paint and varnish manufacture in that region.

Forestry authorities in various States of the South have recommended the growth of this tree in hilly or rolling areas, where its long tap roots would serve as a protection against excessive erosion and resultant exhaustion of the soil. Such planting may assist farmers in the more economic use of their uncultivated land, since tung trees grow satisfactorily on hillsides and on irregular plots of ground which may be difficult to utilize for general farming. In some localities a few plantings are being made along railroad tracks, highways, and edges of fields, so that the trees, in addition to yielding nut crops, may be used instead of posts for stringing wire fencing. The tung tree is beautiful in bloom and may add greatly to the scenic inducements of the South to attract tourists and vacationists.

Tung-tree groves may be worthy of consideration as a supplementary crop for small landowners. The location of many small groves in the same vicinity, making possible cooperative cultivation and harvesting efforts with proper equipment, should result in more profitable returns to individual planters. It is generally conceded, however, that the success of tung-tree plantings as a business venture will be evidenced principally in large-scale commercial developments in the areas best adapted to their growth.

POTENTIAL AREA OF SUCCESSFUL CULTIVATION

In considering cultivation of the tung tree from an economic standpoint as the source of an oilseed crop, it may be interesting to visualize the possible areas in which *Aleurites fordii* may be successfully grown, guided by our present knowledge of climatic and soil requirements of the tree.

Experimental plantings throughout the United States disclose that the areas for successful commercial growing of tung trees will probably be restricted to a rather narrow strip of land, in most places probably 100 miles wide, or less, embracing the southern portions of the States of Alabama, Mississippi, and Louisiana, the north third or half of the Peninsula of Florida, the eastern and northern Gulf counties of Texas, and the southern and southeastern sections of Georgia.

Mature tung trees have been known to withstand severe temporary droughts without serious injury, but generally a minimum annual rainfall of 30 inches is considered essential to satisfactory growth, while best results are apparently obtained in regions where the rainfall averages over 40 inches each year. The western limit of successful planting is considered at about 98° longitude, in Texas, since experiments made in California and other regions west of that line have shown that the rainfall there was insufficient or too irregularly

distributed throughout the year to furnish proper nourishment to the trees.

The southern and northern limits of tung-tree culture will be determined principally by temperature considerations. The tree is deciduous and therefore thrives best where there is sufficient cool weather to allow for a dormant period, but only in regions where early or late frosts will not injure the fruit-bud growth. Young trees not thoroughly nourished or not completely dormant often succumb to a sudden drop in temperature below 20° F. On the other hand, older trees have been known to withstand a temperature below 10°. Therefore in Texas, Louisiana, Mississippi, Alabama, and Georgia, the northern half has proved to be unsuitable, owing to frequent and rather extended frost occurrence. Records indicate that a few trees have lived for several years and borne fruit in various districts of Arkansas, South Carolina, and North Carolina, but usually have failed to maintain a uniformly healthy growth or to yield an appreciable nut crop, and all have later died from cold.

Figures 15 and 16, showing the average annual duration of frost periods and rainfall distribution in the South, may serve to guide prospective planters and to illustrate the limits described.

SOIL AND DRAINAGE REQUIREMENTS

Soil and drainage requirements of the tung tree will largely determine the regions within the potential growing area which will successfully foster commercial plantings.

Although reports from China have suggested that both *Aleurites fordii* and *Aleurites montana* will enjoy fair growth in practically any type of soil, much better results have been obtained in the United States through proper soil selection, and adequate consideration should be given to this factor in choosing areas for commercial planting. In China the tung tree ordinarily has a productive life span of 15 to 20 years in the poor hillside soils in which it is commonly grown, but in more suitable soils it may show satisfactory yields for 30 years and even longer.

Aleurites fordii has apparently very marked soil preferences, based upon the nutriment demands of the tree. Its root structure and general rapid growth demonstrate that it is a heavy consumer of nitrogen and water. Plant foods should necessarily be available in soluble form so that the tree may readily take them from the soil. This fact illustrates the definite relation of rainfall to soil in tung-tree culture to allow full advantage of nutriment present in the soil and to insure constant and vigorous feeding of the tree. Rather heavy and fairly evenly distributed annual precipitation, particularly important during the periods of growing and fruiting activity in the spring, summer, and early fall, is therefore considered essential to prolific growth of the tung tree.

Plantings in the United States have been made on a variety of soils, but planting experience has not yet been sufficiently widespread to indicate definitely the most suitable soil types upon which to grow the tung tree. Satisfactory growth has been reported on well-drained soils of the Orangeburg, Greenville, Norfolk, Ruston, Tifton, Susquehanna, Fellowship, Hernando, and Gainesville series.

The character of the soil may determine the extent and character of fertilizer required.

Soil uniformity over large areas is very desirable in commercial planting, since this condition contributes to the rather even development of the trees, tends to equalize drainage over the region, and indirectly reduces the cost of oilseed production by allowing standard practices of planting, cultivation, and fertilization.

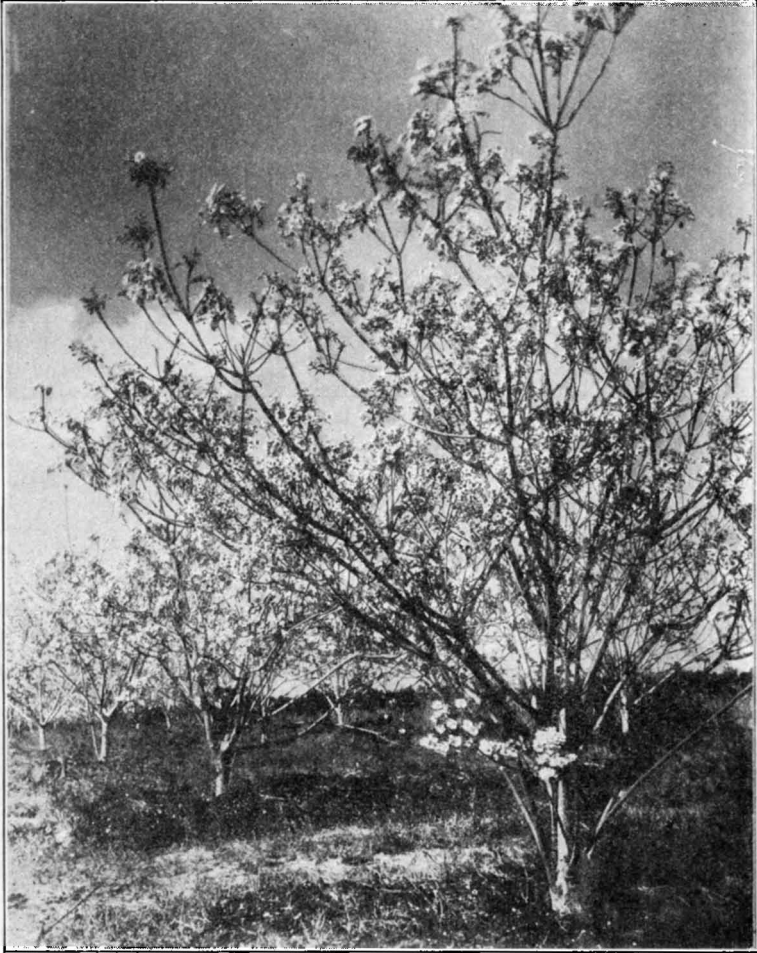


Figure 17.—Grove of blooming tung trees in Florida.

It has been very definitely established in American experience that an acid soil should be selected. Just how strongly acid the soil can safely be has not been proved, but it is considered desirable to plant tung trees in soils having a pH from 5 to 6.8. (The term pH has been used in recent scientific agricultural practice as a measure of soil reaction. Neutral soils have been assigned a pH of 7, figures above that standard indicating an excess of alkali, and lower figures denoting an acid predominance in the soil.) Neutral soils are not

considered particularly adapted and require considerable attention, while alkaline soils have proved injurious to the growth of the tree. Planting experiments in the United States have shown that lime or any other source of alkalinity is detrimental to the development of the tree, even when present in the lower subsoil.

Excess lime content, for example, has resulted in a stunted and unhealthy growth of the trees and a chlorotic condition of the leaves. Also, the bronzing of the leaves and the gradual death of the whole tree has been caused by excess tricalcium phosphate in the soil.

All authorities agree that good drainage is absolutely essential to the best growth of the tung tree. Soils should be of a character to allow satisfactory passage of rainfall, and it is even requisite that the lower subsoils permit easy seepage of water to lower levels. Sufficient porosity to allow air penetration is considered desirable as an aid both to proper soil drainage and to feeding of the roots.

From the foregoing presentation of essential soil and drainage factors, it appears likely that the poor drainage characteristic of certain sections of Louisiana and other Gulf States would naturally eliminate a considerable acreage in that area from consideration, while alkaline soil and prevalence or spotty occurrence of phosphates or lime would restrict development in some counties of Florida, and to a degree elsewhere in the South.

PRESENT PLANTING AREA IN THE UNITED STATES

Progress in adaptability of the tung tree to widespread areas in the South may be visualized from Figure 18, which shows the regions in which favorable growth or commercial planting has been achieved. For the purposes of this study, total tung-tree acreage in a county in excess of 500 acres has been considered commercial planting. Favorable growth indications are based upon rather conclusive evidence of successful experimental or small-scale planting. These two designations, however, do not necessarily imply uniform promise throughout the counties for which they were reported. Absence of markings does not indicate lack of possibilities, but merely the absence of data or of actual plantings upon which to comment.

STATUS OF GROVE DEVELOPMENT

Although definite current reports are not available from all plantings, an attempt has been made to ascertain the acreage in groves of tung trees in the United States in the spring of 1932 to illustrate statistically the progress and present development of this undertaking within the present growing area. Carefully checked estimates based on available data indicate that the total acreage in tung trees in the United States on April 1, 1932, was between 28,750 and 31,000 acres, distributed as follows:

ESTIMATED ACREAGE¹ OF TUNG TREES IN THE UNITED STATES AS OF APRIL 1, 1932

State	Minimum	Maximum	State	Minimum	Maximum
Florida.....	14, 000	15, 000	Alabama.....	600	750
Mississippi.....	10, 500	11, 000	Texas.....	400	500
Georgia.....	1, 750	2, 000			
Louisiana.....	1, 500	1, 750	Total.....	28, 750	31, 000

A minimum and maximum figure is selected for each State to allow for numerous individual trees and small groves known to exist but for which definite acreage figures are not available.

A detailed description of planting by States is presented to show the character, location, maturity, and comparative progress of groves in each of the planted areas.

FLORIDA

Until very recent years tung-tree planting in the United States was confined principally to Florida. Its initial development there reflects the great interest in new crop possibilities which has been manifested in Florida during the past decade. During the early period of introduction of *Aleurites fordii*, other Gulf States were concerned mainly with standard money crops, such as cotton, cane sugar, rice, peanuts, fruit, and general truck produce, from which good returns were being received. Also, available timber resources had not been sufficiently exhausted at that time to attract serious attention to the problem of the economic utilization of cut-over lands.

Two distinct periods of development are noted in the progress of tung-tree planting in Florida. The first, covering the years 1907 to 1923, was characterized by adaptation and cultural experiments conducted on a small scale, while the second includes the subsequent years, during which substantial progress has been made in propagation of the tree.

Early experimental plantings, which were quite successful in northern and central Florida, tended to encourage further development of plantings throughout the State. Climatic conditions were found to be favorable to the healthy development of the tree, infrequent frosts and ample rainfall being cited as definite advantages of the Florida areas. The year 1924 witnessed the beginning of commercial-grove development, a movement which has gained increasing momentum in Florida since that time. The following tabulation indicates statistically the progress of plantings in that State.

TUNG-TREE PLANTING IN FLORIDA, 1923-1932

Year	Total acreage (esti- mated)	Annual increase in acre- age	Year	Total acreage (esti- mated)	Annual increase in acre- age
1923.....	140		1928.....	4, 000	1, 000
1924.....	300	160	1929.....	5, 500	1, 500
1925.....	1, 020	720	1930.....	7, 750	2, 250
1926.....	2, 000	980	1931.....	11, 500	3, 750
1927.....	3, 000	1, 000	1932 (as of Apr. 1).....	14, 500	3, 000

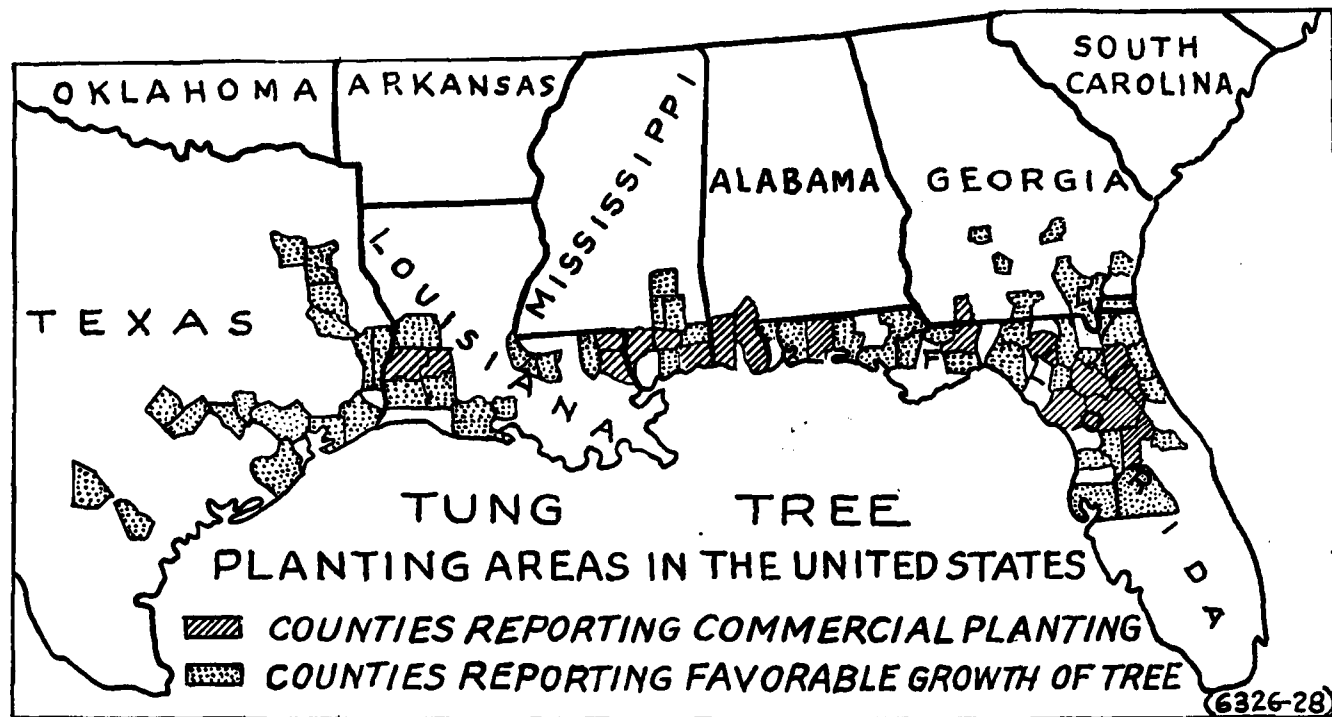


Figure 18

Estimated on acreage planted the number of bearing trees increased from 3,300 in 1924 to over 400,000 in 1931. During 1932 nearly 150,000 more trees will reach initial bearing age.

Although plantings of tung trees were first established in Leon County, the center of activity shifted early in 1923 to the Gainesville



Figure 19.—Tung-tree nursery in Florida

region, in Alachua County, influenced to some extent by the important experimental plantings being carried on in that vicinity by the American Tung Oil Corporation and by the State agricultural experiment station. Commercial-grove development has radiated to

neighboring counties since that time, the major plantings now being reported in Alachua, Clay, Putnam, Marion, Levy, and Lake Counties, as well as in the original Leon area surrounding Tallahassee. Extension of established groves in north and central Florida was most marked during 1930 and 1931, and several new projects of outstanding importance in that region were initiated during this period. Extensive nursery planting and experimental work are being carried on farther south in Polk and Hillsborough Counties. Very recently large groves have been set out in Suwanee County, in north Florida, and in Okaloosa County, in the extreme western part of the State.

Individual plantings are numerous and show considerable variance in size. About 10 large companies are developing tung-tree acreage in Florida, their groves ranging from 750 to over 2,000 acres each. A large number of plantings of 10 to 200 acres are reported, many of which are engaged principally in raising nursery stock for sale to the large planters. Experimental growth of the tree is still being undertaken, and many sections of the State have reported favorable results which seem to justify large-scale activity.

The outstanding contributions of the Florida developments have been in the field of planting and technical research. Active and exhaustive adaptability trials to discover the climate and soil conditions which would foster the best development of the trees have been conducted continuously since 1912 by the experiment station at Gainesville and since 1923 by the American Tung Oil Corporation in cooperation with many private investigators and planters who have reported periodically to those research agencies. Activity in horticultural research in connection with tung-tree plantings has been most marked during the past three years, a period which has witnessed the greatest progress of this important oilseed industry in the United States. Harold Mowry, of the University of Florida, has been one of the outstanding scientists engaged in this work.

Careful studies of planting practice, soil reactions, fruit-bud development, suitable cover crops, fertilizer requirements, relative yields, and many other pertinent subjects have been made, and conclusions have been reached which have served to enlighten prospective planters and encourage the extension of commercial groves within the State. Chamber of commerce officials and county and State groups have been particularly active in stimulating interest in the possibilities of the tung tree in the Florida area. During the spring of 1932 the Gainesville Chamber of Commerce directly aided in fostering development by arranging with large nursery owners for the distribution of nearly 100,000 yearling trees to interested Florida farmers in locations certified by county agents to be suitable for tung-tree plantings.

MISSISSIPPI

Planting progress in Mississippi has been one of the outstanding features of domestic tung-oil development during the past few years. Only a few experimental adaptability tests were previously made in the State, and active interest was not evident until the spring of 1928. Nevertheless, at present Mississippi possesses, at Picayune, the largest individual tung-tree plantation in the United States, aggregating over 7,500 acres, as well as a number of other

groves of substantial acreage, and is approaching Florida in respect to total acreage planted.

From scattered early plantings and later investigations of soil and climatic conditions it appeared that certain sections of the State were well adapted to the growing of the tung tree. Desirable soil characteristics, good drainage, and well-distributed annual precipitation in southern Mississippi were considered especially favorable to development in that region. Prior to actual development, Mississippi planters carefully studied all previous practice in Florida and other States and selected improved procedure adapted to the character of plantings proposed.

In general, however, the concept of tung-tree planting differs materially in Mississippi from that prevailing in other regions. The setting out of extensive individual groves and the attainment of low planting costs per acre by the use of machine methods of clearing, planting, and cultivating were undertaken. Minimum cultivation and fertilization were contemplated initially, by reason of the natural richness of the soils. Substantial profits were visualized, even in the face of possible lower nut yields, by means of large-scale activity, the distribution of the overhead of operation over an extended acreage, and the resultant low cost of production per acre, in contrast with Florida methods predicated upon intensive cultivation and fertilization, with particular attention to high yields per tree and per acre.

The progress of tung-tree plantings in Mississippi resulted primarily from the growing realization of the need for profitable utilization of cut-over timberlands and the desire of lumber companies to diversify their activities. Timber-tract owners and important southern lumbermen are identified with the principal tung-oil developments in that State.

The availability of extensive tracts of such land was conducive to large-scale development. At present over 90 per cent of the acreage in Mississippi represents the planting efforts of five large commercial-grove enterprises.

The principal plantings thus far have been recorded in Pearl River, Stone, and Jackson Counties, supplemented by smaller developments and experimental plots reported in Forrest, Perry, Jones, George, and Harrison Counties. Nursery plantings are well developed, the largest of which are maintained by the owners of the leading commercial groves.

Large tracts of land in southern Mississippi are available for development of commercial groves. Much of this acreage is considered eminently suited to the growth of *Aleurites fordii*, and plantings now contemplated are expected to amplify considerably present tung-tree acreage during the next few years. Most of the Mississippi tung trees are now 1 to 5 years old. One of the leading companies operating in the State, anticipating nut-crop production in 1933, plans to install a modern tung-oil mill in the near future. The first substantial tung-nut crop in Mississippi was recorded in 1931, when 40,000 pounds of nuts were harvested.

LOUISIANA

Early plantings of *Aleurites fordii* from trees sent out by Doctor Fairchild in certain sections of Louisiana gave promising results.

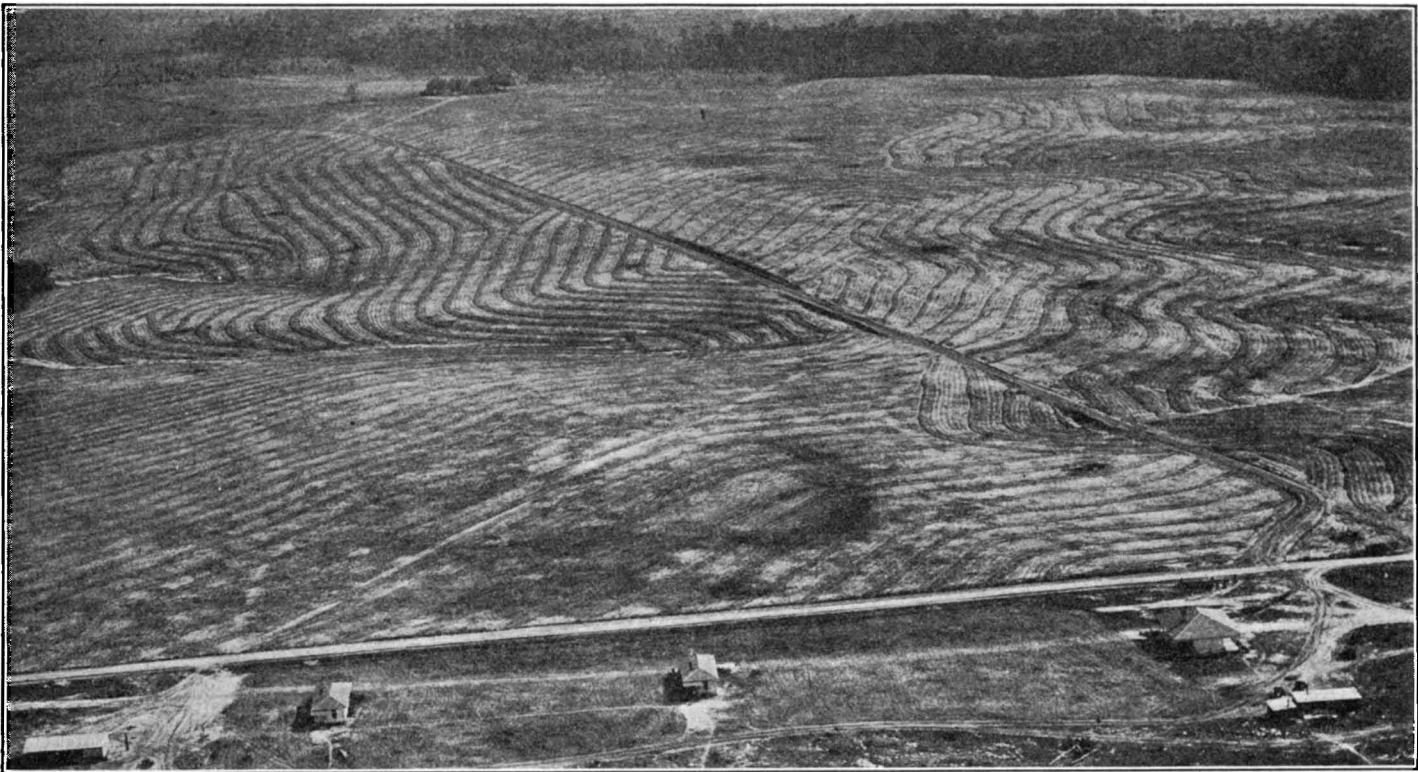


Figure 20.—Airplane view of 4,000-acre tract in Mississippi, showing contour layout of groves and extent of development on this cleared cut-over timberland

Further experimental planting research was undertaken by the State Department of Conservation at testing stations at Woodworth, Jeanerette, Thibodaux, Carlisle, Elizabeth, and Sherburne, during the period 1925 to 1928. Stimulated by publicity relating to possibilities in the State, a number of private individuals, real-estate firms, and lumber companies set out trees in small plots for observation. Poor drainage has restricted development in many sections of southern Louisiana, but several areas have demonstrated their suitability for the cultivation of this tree.

The real development of fair-sized commercial groves was not begun until 1928, and even at the present time the total acreage is not relatively large. Several plantings ranging from 50 to 100 acres each are reported, as well as two outstanding developments on each of which between 350 and 500 acres of trees are being grown. Nut yields were received from about a third of the total acreage in 1931, and over half of the trees will bear a crop in 1932.

The principal plantings of tung trees are at present reported in the parishes of Washington and St. Tammany, although commercial-grove activity is also evident in Beauregard and Allen Parishes in the western part of the State. Grove acreage is being slowly extended elsewhere in Louisiana, and a number of other parishes may soon occupy a more significant position in the Louisiana tung-oil industry.

GEORGIA

Georgia does not report a large commercial acreage devoted to tung trees and has only one area of development. Trial growth of *Aleurites fordii* was attempted at the State experiment station at Experiment, Ga., as early as 1909, and since that time rather widespread experimental plantings have been made within the State. Georgia has proved to be one of the most instructive testing regions for tung-tree culture in the South because of the wide range of soil and climatic conditions prevailing in the various sections of the State in which trial plantings have been made.

Notwithstanding splendid showings of a number of the early plantings, and exceptional yields by certain individual trees in the State, the extension of large commercial-grove activity has not kept pace with such developments elsewhere in the Southern States.

Although plantings as far north as Rome have been recorded, at present the only appreciable development is in the southern counties. The growth of *Aleurites fordii* in the central and northern portions of Georgia is hampered by occasional killing frosts in the autumn and late spring. Commercial planting is not advised by well-informed authorities north of Waycross in southeastern Georgia, or above Tifton in the south-central and southwestern sections of the State.

Existing acreage is mainly in small, scattered tracts, the most numerous developments being reported from Grady County. Large-scale cultivation of tung groves is now contemplated by several growers. Plans for a cooperative 3,000-acre development near Cairo were announced in 1931, and it is reported that over 200,000 trees have been planted on this project since that time.

ALABAMA

The tung tree appears to flourish in the extreme southern portion of Alabama. One of the original plantings in the State, at Satsuma, is now 12 to 14 years old. The trees have attained a height of about 25 feet and have been producing satisfactory nut yields regularly for a number of years. Experimental plantings on a small scale, which have recently fruited satisfactorily, have been reported as far north as Montgomery, but potentialities of commercial development that distance from the Gulf are restricted by the frost hazard.

The principal plantings of tung trees in Alabama have been made in the southern tip of the State, in Mobile and Baldwin Counties. The development thus far has been confined to a considerable number of small plantings from 5 to 150 acres in extent, mainly devoted to experimental planting for seed, although several commercial nurseries of fairly good size have been established. About half of the existing acreage is now at least 3 years old. The seed crops are at present largely employed for the extension of existing groves or are sold to other planters.

It is not definitely known to what extent plantings will progress in this area, but interest is developing particularly among owners of cut-over timberlands.

TEXAS

The preliminary experimental growth of the tung tree in Texas was carried on principally at the State experiment station and its substations at Troup, Nacogdoches, Beaumont, Angleton, and Beeville. These small trial plantings, some set out as early as 1908 and 1909, have consistently produced fair nut crops without fertilization and cultivation. It was not until 1928, however, that general planting of the trees was recommended in eastern Texas by State agricultural officials. In 1929 seed was distributed by the Texas Experiment Station, upon request, to 110 prospective planters in various sections of the State.

Initial reports of germination and growth from these planting efforts showed that the southeastern part of the State apparently was most favorable for commercial development of tung-tree plantings, northeastern Texas being handicapped by the possibilities of fatal temperatures every 7 to 10 years. Promising results were obtained in the eastern Gulf Coast counties and in Jasper, Newton, and Smith Counties. Isolated cases of good showings were reported at McDade in Bastrop County and at Pleasanton in Atascosa County. Several lumber companies have recently established small groves in eastern Texas, to test the adaptability of the tree for growth on cut-over pine lands in that region. One of these firms plans to set out about 2,000 acres during 1932 and 1933 in Angelina County.

It is believed that commercial success may be obtained in the rain-belt areas of Texas, where the lands are generally well drained, free from lime, and subject to fairly favorable climatic conditions. A somewhat substantial part of the reported acreage will reach bearing age in 1933, at which time more accurate comments on possibilities in Texas can be made.

CULTIVATION AND FERTILIZATION METHODS

Nursery-bed seedlings require frequent shallow cultivation to eliminate weed growth and to keep the soil from packing too greatly about their slender, growing stalks. Young transplanted trees also need fairly close attention to prevent choking by other vegetation and to keep the top soil in good condition. Mulches of coarse material have shown their value in keeping down weed growth and in preserving soil moisture during dry periods. Cutting back of yearling trees is sometimes employed to cause lateral branching close to the ground. As the trees mature, cultivation efforts may gradually be diminished, since the thick foliage which develops tends to shade areas beneath them and thus discourages grass or weed stands.

Most trees yielding fruit or nut crops require periodic chemical spraying as a protection against insect attack or fungus growths. Fortunately, the tung tree has not been materially affected by these annoying and oftentimes expensive pests. Up to the present time, only one root parasite (the nematode), one fungus disease (the thread blight), and one bacterial disease (a leaf spot) have been found attacking it. Three species of scale insects—the latania, cottony cushion, and ivy scales—have been noted on tung trees. As these evidences of parasitic attack are not prevalent, however, and do not at present constitute an important problem of tung-tree culture, spraying of the trees has not proved necessary as yet.

AMERICAN PLANTING PRACTICE

The hulled seeds of the tung fruit or nut are customarily employed to propagate this tree species. Planting of the whole fruit is not considered desirable, since this method does not tend to develop straight, vigorous stock.

CARE OF SEED

Tung seeds retain their power of germination for only a limited period and planting should, therefore, take place during the season immediately following their maturity. To retain proper viability in the seeds, they should be properly stored in the interval between the harvesting and planting seasons. The ripe seeds keep fairly well in the original husks, and bagging and storage in a dry place in this form have given satisfactory results. Careful seed selection from trees of proved merit is recommended by botanical authorities as the means of securing favorable growth of trees and maximum yield of nuts. The practice of budding upon 1 or 2 year old tree stock has been successfully employed by some horticultural experts to perpetuate a particular variety or strain.

VARIETIES PLANTED

There are two types or varieties of *Aleurites fordii* planted in the United States. One, a so-called single type, bears but one fruit per twig, whereas the other, known as the cluster variety, yields from 2 to 20 in a group. In Florida authorities report that the cluster type produces the highest yield of nuts per tree, although it is contended by certain other investigators that the size and oil content of the individual nut is considerably lessened by this multiple bearing;

in Mississippi and Louisiana the single-fruited variety seems to be preferred.

METHODS OF PLANTING

In planting, two methods have been employed: (1) The development of seedling stock in nurseries, followed by transplanting, and (2) the direct planting of seeds to grove acreage. The first-mentioned practice has been the most common in domestic plantings up to the present time. Seeds are usually planted to nursery beds in February or March. In nurseries general procedure indicates a depth of 2 to 4 inches and a spacing of 8 to 12 inches apart, with rows not less than 3 to 4 feet apart. Germination occurs in about

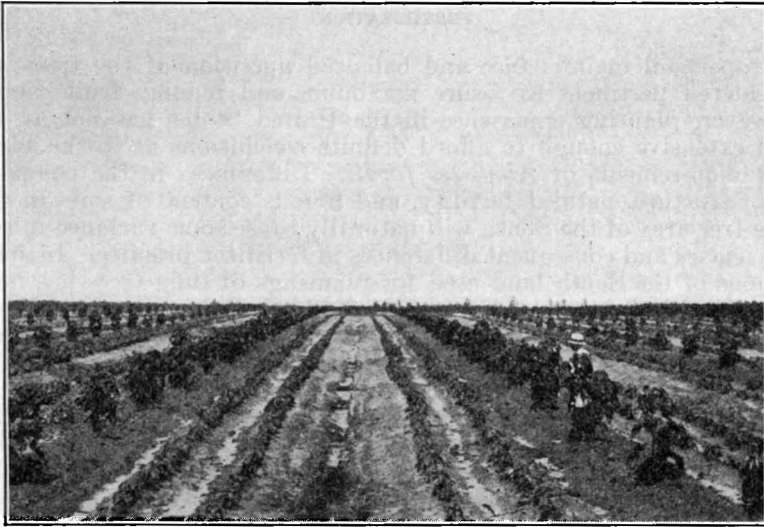


Figure 21.—Florida tung grove showing the planting of nursery stock between the rows

60 days, and transplanting to grove locations is recommended usually after one year's growth. Seedlings of that age will, under proper conditions, attain a height of 3 to 6 feet.

Only healthy nursery stock should be chosen for grove planting, and transplanting should take place only while the young trees are dormant. The roots of young trees should be guarded from unnecessary injury and the trees should not be planted too deeply in their new positions. Both top and root pruning before setting out nursery stock to groves has been advocated by some commercial planters to facilitate transplanting and to establish a proper balance between the branch area and the supporting root area. Proper development of the root system is considered pertinent as a foundation for later growth of the tree, in decided preference to the initial pronounced stimulation of top growth and foliage at the expense of the underground feeder roots.

SPACING OF TREES

Practice and opinion relative to spacing of the trees in groves varies greatly. The number of trees planted ranges from 60 to 116

to the acre in different developments, although 100 per acre is considered an average spacing. Regular spacing of the trees in rows has been employed in most of the plantings made to date, with distance between the trees allowing for proper expansion of the branch and root systems. The fact that many full-grown trees have a spread of 25 to 40 feet has prompted the suggestion that in commercial groves alternate trees be removed after the seventh or eighth year to avoid crowding and consequent curtailment in nut yield of individual trees. Branch pruning or staggering of trees in the groves as a means of permanently maintaining a satisfactory distance between the trees also has its adherents. Contour planting, following the natural slope of the land, has been practiced in Mississippi. (See fig. 20.)

FERTILIZATION

Proper soil maintenance and balanced nutrition of the trees are considered pertinent to assure maximum and regular fruit yields. However, planting experience in the United States has not as yet been extensive enough to afford definite conclusions as to the fertilizer requirements of *Aleurites fordii*. Differences in the composition, structure, natural fertility, and humus content of soils in the tung-tree area of the South will naturally cause some variance in soil deficiencies and consequent differences in fertilizer practice. In some sections of the South land used for plantings of tung trees has been considered sufficiently rich in plant foods to foster the satisfactory initial growth without fertilization, but the heavy drain of constant fruiting eventually may show the necessity of periodic applications of fertilizers even in this region.

Experiments in Florida have rather clearly indicated that the tung tree matures more rapidly and produces larger nut yields with fertilization. These tests have shown that the presence of adequate nitrogen plant food is essential. Complete mixtures containing nitrogen, phosphoric acid, and potash apparently have given the best results of all materials applied on Florida groves, although some growers report that the use of organic fertilizers alone in proper quantities has produced a thrifty growth.

The planting of leguminous cover crops, such as crotalaria, velvet beans, soybeans, cowpeas, and beggarweed, between the tree rows is considered good practice in certain areas, since it adds materially to the nitrogen and organic content of the soil. These plants should not be sown too close to young trees, and those varieties subject to nematode attack should not be employed.

HARVESTING THE NUT CROP

The harvesting of the nut crop of the tung tree does not constitute an important problem. The fruits ripen in late autumn and gradually drop to the ground. Several weeks elapse between the first fall of ripe nuts and the final dropping of the last ones. Customarily they are allowed to remain on the ground, and may all be gathered at one time. Hand labor is at present employed to pile the nuts for wagon collection. On commercial plantings extending over a considerable acreage, however, gathering by machinery may eventually prove feasible.

NUT-CROP YIELDS

Domestic tung-tree plantings in general have not attained a sufficient age to allow an accurate computation of probable or average nut yields per tree or per acre from plantings in different stages of maturity. Authorities seem to agree that under favorable conditions and after the tree attains full growth, better yields of oil per acre will be obtained from plantings of tung trees than from most other oilseed crops, including flaxseed.

Aleurites fordii does not customarily reach commercial bearing until the fifth or sixth year. The number of trees in the United States over that age is relatively small, and in most instances a regular record of yields has not been kept. Also, these early plantings have largely been experimental, and in many cases yields have been adversely affected by errors in soil selection, planting practice, and fertilizer application. However, the following rough estimates of annual yields, based on scattered data for selected individual trees and certain grove acreage, may assist planters and other interested parties in appraising the possible returns from this new American oilseed crop activity. Marked variation in yields reported for trees of the same age has necessitated the wide range shown in the following figures.

ESTIMATED YIELDS OF NUTS AND OIL FROM ALEURITES FORDII

[Under most favorable conditions of soil, drainage, and fertilization]

Age of tree	Weight of nut yield ¹		Approximate yield of oil (pounds per acre) ²
	Pounds per tree	Pounds per acre ³	
Third year.....	4-8	400-800	72-144
Fourth year.....	13-20	1,300-2,000	234-360
Fifth year.....	27-40	2,700-4,000	486-720
Sixth year.....	45-55	4,500-5,500	810-990
Seventh year.....	61-70	6,000-7,000	1,080-1,260
Eighth year and thereafter.....	80-90	8,000-9,000	1,440-1,620

¹ Weight of unhulled fruit.

² Based on an average planting of 100 trees to the acre.

³ Computed at 18 per cent of the total weight of unhulled fruit, the average oil yield reported by the modern tung-oil mill at Gainesville, Fla.

In China the annual nut yield from mature trees weighs generally between 20 and 50 pounds. Yields in the United States of 175 to 200 pounds of nuts by individual trees 10 to 14 years old have been recorded, and higher acreage returns than those given in the foregoing table may possibly be attained when existing commercial plantings reach a more advanced age. Widespread planting research in the United States has contributed materially to general knowledge of the characteristics and requirements of the tung tree. Improved planting practices have resulted which will undoubtedly tend to increase nut yields.

OIL EXPRESSION IN THE UNITED STATES

Planting progress has now reached a fairly advanced stage, and nut crops expected during 1932 and 1933 would appear to warrant



Figure 22.—Five-year-old tung tree in bearing

erection of more adequate milling and expression facilities. At present only one commercial plant is in existence. This is located at Gainesville, Fla., and is capable of handling only a portion of the present and potential yield of the planted acreage in that State.

EARLY EXPERIMENTS

In considering the establishment of tung-oil mills in the United States, a knowledge of experiments conducted in evolving present machine methods of expressing tung oil would appear to be essential. A large share of the investigational work conducted along this line has been carried out at the suggestion and under the direction of the American Tung Oil Corporation. The cooperation of prominent paint and varnish manufacturers, interested oil-milling companies, and machinery manufacturers enabled the corporation to investigate and compare results obtained with different processes and types of machinery under widely varying conditions. Tests conducted by the American Tung Oil Corporation or under private auspices brought to light certain outstanding facts pertaining to milling procedure, as well as important conclusions relative to the equipment most desirable for commercial expressing operations.

The earliest important test using domestic tung nuts was made by Henry Gardner at the laboratory of the Institute of Paint and Varnish Research in 1924. The necessity for more extensive study of expression methods to secure accurate and conclusive results was evident at that time, although some fairly definite indications of the importance of proper drying procedure were obtained. Consequently, expression experiments were conducted on a larger scale by the American Tung Oil Corporation and by cooperating agencies in the early months of 1928, employing nearly 14 tons of American-grown seed from the 1927 crop.

A number of different mechanical devices for hulling and separating tung seeds were tested, but the most satisfactory appeared to be a ball-bearing disk hulling machine which could be adjusted to control the amount of pellicle left on the kernels. This machine decorticates the whole fruit and discharges the broken hulls and seed to shaking trays, allowing the passage of only the seed to trays below. The hulls are carried from the upper trays on a moving belt and removed by suction to a storage compartment, while the seeds are passed through an air suction chamber to remove hull particles and are then deposited at the end of the machine, where they may be inspected and bagged or conveyed to other equipment for meal-cake preparation and ultimate expression of oil. In trial tests this huller allowed an intake of 3,000 pounds of fruit hourly with an output averaging 36 per cent by weight of cleaned hulled seed ready for expression.

The principal early problem of mechanical technicians interested in evolving tung-oil milling procedure was the selection of the best method by which to remove the oil from the seed. Three distinct processes were employed experimentally. Expeller methods were somewhat generally conceded to be the most practical because of the greater efficiency and lower cost of operation of this type of equipment. Fairly good results were achieved in the use of volatile solvent and in hydraulic expression. Difficulties were encountered in

the selection of a suitable solvent and in the production of a solid white mass (beta-elæostearin) in the first instance, and in obtaining a good yield of oil in the latter case. These latter two methods may be improved in coming years and be found more adaptable to the expressing of tung oil, but present opinion seems to favor the installation of expeller machinery. In the expeller equipment, pressure on the meal up to about 12,000 pounds per square inch is built up between a cylinder of chilled steel bars and a central shaft of broken-screw design. The oil flows out through the fine openings between the bars and the remaining fibrous paste or oil cake is discharged at

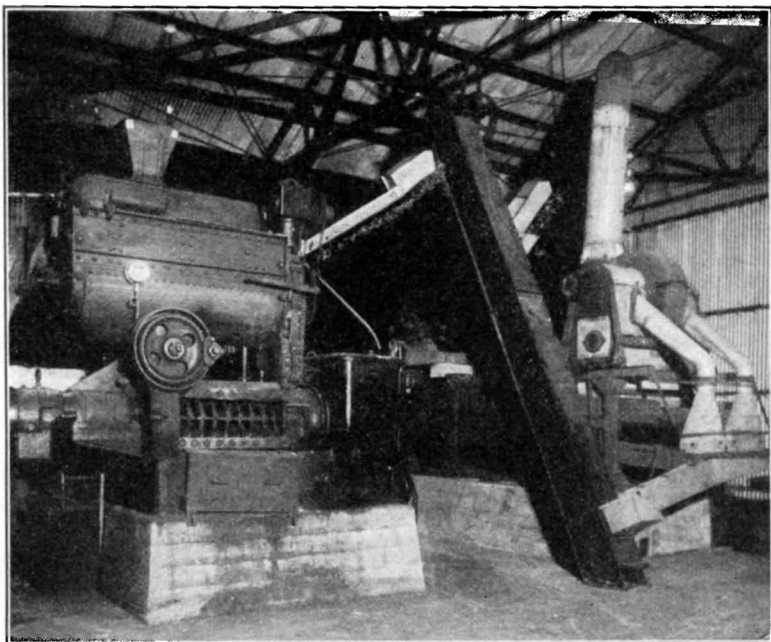


Figure 23.—Modern tung-oil mill at Gainesville, Fla., showing machinery employed in hulling nuts and expressing the oil

the end. This method has been classified as a cold-press process, although the meal is customarily preheated by steam in a jacketed chamber and some friction heat is generated during the pressing. Temperatures attained, however, are generally below 100° C.

FIRST COMMERCIAL PLANT

The first commercial plant for the expression of tung oil was established at Gainesville, Fla., in the fall of 1928. Selection of machinery was influenced by the conclusions reached in experimental trials discussed previously. The equipment, installed in the central portion of the plant, included a disk huller with special separator attachments, a grinding machine for reducing the cleaned kernels to meal, and a medium-sized expeller unit for expression of the oil. Mechanical conveyors were used to connect the three principal machines in the mill, thus allowing continuity of operation. Storage bins for nuts and a well-ventilated room for drying the fruit are

located at one end of the plant, and three oil-storage tanks and laboratory facilities are situated at the other end.

The desire of tung-tree planters to utilize their nut production for expansion of acreage has restricted somewhat the quantity of seed available for expression in this plant. Therefore the plant was operated for only about one week in each of the years 1929, 1930, and 1931 and during four weeks in 1932. Tung-oil production in this mill amounted to 12,000 pounds in 1929, 20,000 pounds in 1930, 25,000 pounds in 1931, and 130,000 pounds in 1932.

Oil yield from nuts expressed in the Gainesville plant has shown considerable variance, reflecting differences in the age of the trees from which they were obtained, in soil types, and in other factors.

In operations at the Gainesville plant it has been found that the hull removed in the decortivating process comprises about 64 to 66 per cent, by weight, of the whole dried fruit. The oil is derived from the clean kernels making up the 34 to 36 per cent remaining. Based on the weight of the nuts taken by the mill and the weight of oil expressed, it has been computed that the oil output constitutes about 16 to 20 per cent of the total weight of the unhulled dried fruit.

Contrast with results obtained with primitive presses in China can best be made by comparison of the average yields from the meal. The following figures for oil and oil-cake production in China and the United States are computed on the total weight of the meal (moisture and foots discarded or lost in the operation accounts for unenumerated remainder).

Production in China:	Per cent
Oil.....	30 to 35
Press cake.....	52 to 58
Production in the United States:	
Oil.....	40 to 44
Press cake.....	42 to 46

In China a second run of oil from the cake is often made, but the oil thus produced is of a very inferior grade and is not suitable for export. For practical purposes only a comparison of first-grade oil in either case is made. Even with American expeller methods, from 5 to 6 per cent of the total oil content of the meal is left in the press cake, as compared with between 8 and 12 per cent not recovered in China. American oil yields have been restricted somewhat by the irregular operation of the mill in short periods.

MACHINE EFFICIENCY

Although the huller proved capable of decortivating and separating 5,000 pounds of fruit an hour, the most efficient results have been obtained with a production speed of 3,000 to 4,000 pounds an hour. The output and rate of operation of the huller depends in a large measure upon the dryness and uniformity of the fruit. Expeller machinery employed has expressed as high as 550 pounds of meal an hour, but the average intake is 516 pounds.

COST OF OIL EXPRESSION

Present experience in expressing tung oil is limited, and only approximations based on the part-time operation of the Gainesville mill can be presented as an index to probable expression costs.

The engineer in charge of that plant estimates that it would cost about \$4 a ton to hull and express tung nuts, with the mill in operation 24 hours a day, 5 days a week, for 10 months of the year. Yields of oil in part-time operation during the past four years have ranged from 312 to 392 pounds per ton of dried fruit. Based on these yields, complete preparation of the oil would cost between 1 and 1½ cents per pound. Better yields of oil will doubtless result from continuous operation and will thus curtail somewhat the unit cost of expression. Also, it is possible that a market may be developed for the tung-oil press cake, which will indirectly reduce expression costs.

BY-PRODUCTS OF TUNG-OIL EXPRESSION

The husks removed from the seed prior to expression contain such a small plant-food content that they appear to be practically useless for commercial sale as fertilizer material. However, the pomace or residue remaining after extraction of the oil has a fairly high fertilizer value, said to be comparable with that of castor pomace or cottonseed meal.

In the following figures fertilizer values of tung-oil cake from American tung nuts are contrasted with those for castor and cottonseed by-products.

RELATIVE FERTILIZER CONSTITUENTS OF TUNG OIL AND CASTOR OIL POMACE AND COTTONSEED MEAL

Fertilizer constituent	Tung-oil pomace	Castor-oil pomace	Cotton- seed meal
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
Nitrogen (N).....	5.5-6.5	4.1-6.6	6.7-7.4
N equivalent to NH ₃	6.0-7.3	5.0-8.0	7.0-9.0
Phosphoric acid.....	1.7-2.5	1.0-1.5	2.0-3.0
Potash (K ₂ O).....	1.2-1.3	1.0-1.5	1.5-2.0

It has been considered in the United States that the fertilizer value of the press cake might offset the cost of crushing the tung nuts. This conclusion has been based primarily on estimated possible returns from the sale of tung-oil pomace, computed from quotations per ton of other organic materials. Prices of organic fertilizers have shown a steady downward trend during the past few years, and predictions as to the prospective demand or future price level of such materials can not safely be made at this time. In general, the future of organic fertilizers does not appear promising, in view of the growing market for synthetic materials and compound fertilizers of much higher plant-food content. The nearness of the large fertilizer markets of the Southern States to the tung-oil developments, however, may prove favorable to the sale of tung-oil pomace when commercial tung-oil expression becomes established in this country. Because of its very laxative properties the tung-oil press cake would apparently be unsuitable as a stock feed and therefore would not have the double market utility characteristic of many other expression by-products. This material will probably find its greatest use in fertilizing the tung-tree groves and may thus prove of appreciable value in reducing operating costs of such plantations.

FOREIGN TUNG TREE PLANTINGS

The earliest known efforts to introduce the tung tree to foreign soil and climatic conditions were largely coincident with investigations of potential money crops for the colonial possessions of the larger European countries. The foresight of botanical research antedated the real development of the Chinese export trade in tung oil. The Kew Gardens in London in 1880 dispatched seed of *Aleurites fordii* for cultivation experiments in Ceylon, British Guiana, Dominica, Jamaica, and Zanzibar. As a result of promotional effort at the Calcutta exposition, the trees were planted experimentally in India in 1883 and 1884. Efforts to extend the tung-tree areas in Tonkin by French colonial authorities were made as early as 1882. In 1887 La Société Nationale d'Acclimation offered a prize for the successful cultivation of the tung tree in the French colonies. Trial plantings of fair success were reported in Madagascar and Reunion in the period 1892 to 1895, while attempts at propagation in Algeria at that time were not particularly encouraging. Subsequent efforts to increase plantings in the French oversea possessions were actively sponsored by the Jardin Colonial. German botanists also attempted to introduce and acclimate *Aleurites* in their East African colonies during the latter years of the nineteenth century.

These initial colonial cultivation experiments, although not altogether successful or productive of extended plantings at that time, laid a foundation for later developments and rendered a particularly valuable service in amplifying the then inadequate knowledge of characteristics and essential climatic and soil requirements of the tung tree.

The expansion of the Chinese tung-oil export trade and the more general acceptance of the product both in the United States and Europe during the first decade of the present century resulted in further preliminary investigations of the possibilities of growing tung trees in other sections of the world. Plantings as early as 1904 were made by the Hong Kong Botanical and Afforestation Department, although no conclusive records of the result of this first experiment are available. Seeds of *Aleurites fordii* were dispatched as early as 1911 from the British Royal Botanical Gardens at Kew to the British West Indies and Australia. E. H. Wilson, author of *A Naturalist in Western China*, stated in 1915 that he believed that the tung tree could be successfully cultivated in South Africa, East Africa, Australia, Algeria, and Morocco.

The widespread experimental planting of tung trees in the United States and its later projected development on a commercial scale aided materially in the encouragement of more extensive foreign plantings. Material assistance has been rendered to foreign plantings in the form of selected seed consignments furnished by the American Tung Oil Corporation and other agencies in the United

States. The most important foreign plantings outside the United States have been carried on in the British Colonies and Dominions as a direct result of the interest and encouragement of the Imperial Institute and the cooperative investigational efforts of the Research Association of British Paint, Colour, and Varnish Manufacturers, assisted materially by the financial backing of the Empire Marketing Board. Governmental and institutional experimental foreign plantings have in certain instances paved the way directly or indirectly for present and projected commercial plantation development.

BRITISH EMPIRE EXPERIMENTS

British Empire experiments in the cultivation of the tung tree were undertaken systematically in 1917 upon recommendation of the Raw Materials Committee of the Imperial Institute, but the volume and quality of available tung-nut seed affected materially the extent and result of these early plantings. More concerted effort in the development of Empire cultivation of tung trees was considered by the Advisory Committee of Oils and Oilseeds of the Imperial Institute in 1927, and in cooperation with the Research Association of the British Paint, Colour, and Varnish Manufacturers better quality seeds were obtained from both China and Florida for distribution to experimental stations and private planters in practically every British-controlled area in the world. According to recent reports, experimental plantings are in progress in Australia, New Zealand, New Guinea, Fiji, India, Ceylon, British Malaya, Seychelles, Mauritius, Union of South Africa, Kenya, Nyasaland, Rhodesia, Sudan, Nigeria, St. Helena, Cyprus, Palestine, Bermuda, the British West Indies, and British Honduras. Although results are not available covering all the cultivation efforts mentioned above, the following paragraphs will serve to indicate the progress being made in tung-tree cultivation in various British Dominions and Colonies.

AUSTRALIA

The earliest known planting of tung trees (*Aleurites fordii*) in Australia occurred at the New South Wales Botanic Gardens in Sydney in 1910, with seeds obtained from an Australian traveler in China. Two trees were planted there, one of which has fruited consistently since coming into bearing. Plantings were also made at the experiment farm of the New South Wales Department of Agriculture, at Grafton. However, probably the first real interest in the possibilities of raising tung trees in New South Wales was developed when a 100-tree plantation at Pennant Hills, 18 miles from Sydney, was established by H. Rawes-Whittell in 1926. This development, planted with seeds obtained from the Botanic Gardens and from China, reported in 1930 about 50 bearing trees. Later a 600-tree plantation was set out in the same district. Encouraged by the showing of the Pennant Hills plantings, a firm known as Tung Oil (Ltd.), capitalized at £10,000, was organized in the spring of 1931 to purchase and operate a plantation of 1,000 acres to be established in an adjacent region, 20 miles from Sydney.

The first experimental plantings in Queensland were made by the Queensland irrigation authorities, who were induced in 1927

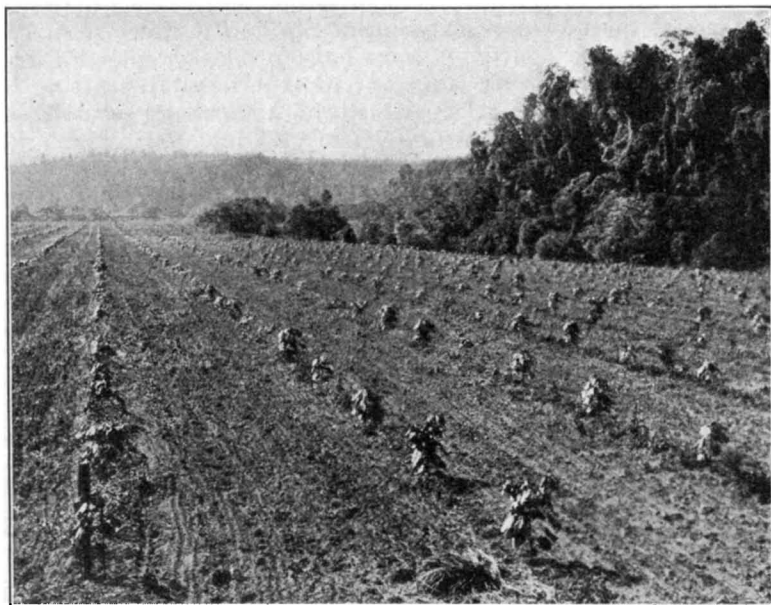


Figure 24.—Tung-tree plantation in North Queensland, Australia, 15 months after planting. Heights of trees range from 4 to 9 feet



Figure 25.—Tung-tree nursery in North Queensland, Australia

to plant a few trees on the Dawson irrigation project near Rockhampton. In 1930 a fair yield of fruit was reported from those plantings. The Queensland Acclimatisation Society also placed out some trees at the Lawnton Experiment Station, 16 miles from Brisbane, which at the age of 4 years have produced splendid fruit. These trees are now being subjected to experimental grafting and pruning. The Queensland Department of Agriculture secured seeds from the Kew authorities in London in 1927 and 1928, which were distributed throughout South Queensland for experimental purposes. However, results obtained from those plantings are not yet available.

The most extensive cultivation of *Aleurites fordii* in Australia is being carried on in the Johnstone River Valley just north of Innisfail, Queensland, where the Queensland Forest (Ltd.) has established a semicommercial plantation of 45 acres to demonstrate the possibilities of the growth of tung trees in Queensland. There are nearly 6,000 trees in this plantation, some of which will probably bear nuts in another year. From all indications it would appear that the area chosen is well suited to the growth of the trees. In choosing the Johnstone River area, the officials were prompted by the fact that candlenut (*Aleurites moluccana*) grows with extreme vigor in the northern coastal areas of Queensland. The rainfall in that region ranges from 80 to 150 inches a year, and soils are composed principally of rich basaltic loams and fertile alluvial mixtures. The company believes that the plantation offers every probability of success and hopes to interest large capital in establishing plantations up to 5,000 acres with central oil-expressing plants.

Australian annual requirements of tung oil during normal years average approximately 1,100,000 pounds. Investigations by experts at the Sydney Technical College indicate that the Australian oil is at least equivalent in quality to the Chinese tung oil imported. Tung-oil interests in Australia believe that, should success attend the efforts to establish tung-oil plantations in northern Queensland, the demand in Australia could be supplied, and further outlets might be found in New Zealand, Great Britain, and the countries of continental Europe.

NEW ZEALAND

Comparatively unknown in the Dominion two years ago, the tung tree at present is reported to have possibilities in New Zealand. Prior to 1929 a number of isolated attempts were made by Government departments and individuals to establish the tung tree in various parts of the country. Some of the seeds for these experiments were procured from China, while others were supplied by the Empire Marketing Board, upon special arrangement with experiment stations in Florida. Principally through lack of technical knowledge these attempts did not go very far beyond the experimental stage, and it was not until recently that any serious attempts were made to develop an industry on a commercial basis.

In 1929 nearly 1,000 specially selected seeds were planted in a garden at Northcote. These attained a height up to 5 feet within the first 12 months. About the same time a further shipment of some 60,000 seeds was received from Florida and planted in a specially selected nursery near Helensville. These also showed a very satisfactory germination and growth, in spite of the fact that the nur-

ery was in an exposed position and subjected to strong winds. Experiments over a period of seven years have indicated that tung trees might be grown successfully on a large scale in certain localities of north Auckland. In most instances experiments have been conducted with the cluster variety.

There are many thousands of acres of unoccupied land available in the northern part of North Island which, it is claimed, are suitable for the cultivation of tung trees. Six or eight companies have purchased land in this section for tung-tree development, and preparations for planting in 1932 are under way. A considerable number of the companies which have been organized to carry on tung-tree plantings in New Zealand depend largely upon stock flotation or upon funds raised by advertising and solicitation.

SOLOMON ISLANDS

Two large planters of copra in the Solomon Islands, namely, the Malayta Co. and the Rere Plantations Co., are conducting tung-tree cultivation experiments. The collapse of copra prices in the British market has turned the attention of planters to the possibilities of tung-oil production, and if present experiments are successful plantings may be undertaken on an extensive scale. The commissioner of lands in the Solomon Islands contemplates the planting of tung-tree seeds on available Government lands in the islands.

INDIA

In view of the existence of wild growths of *Aleurites montana* in certain sections of Burma and India, it was believed that both species of the tung tree could be successfully cultivated in portions of that British Colony. Trial plantings have been undertaken in many sections of this area since 1927. Tung trees were initially planted and grown to seed at the Forest Research Institute at Dehra Dun, United Provinces. Small plantings were also made by the Indian Lac Research Institute in the Ranchi district of Chota Nagpur, India. Although both the above-mentioned plantings have shown satisfactory growth, the most promising developments thus far have been established in Assam and Burma.

Aleurites fordii has shown excellent growth in Assam, and in some instances has fruited when only 18 months old. A number of tea estates have undertaken planting of experimental plots in this Province. Although a complete statement of acreage planted in Assam is not available, citation of one of the principal planting efforts may serve to show the progress of development. D. S. Withers, a tea planter, reported in July, 1930, a nursery of 35,000 yearling trees and a 10-acre grove already set out. One hundred acres additional were planted during 1931, encouraged by the successful fruiting of many of the trees in the original grove. Seventy of the *Aleurites montana* species planted have also shown favorable growth.

The Burma Department of Agriculture has during the past three years conducted experiments in tung-tree cultivation at Maymyo, Mandalay, Hmawbi, and at Taunggyi, Southern Shan States. Al-

though uneven development of the trees has been evidenced at Maymyo and Hmawbi, in general these plantings have shown healthy growth in nursery plots, and few casualties have been recorded in transplanting to small experimental groves. The most extensive plantings in Burma have been carried on by a British company known as Tung Oil Estates (Ltd.), a firm organized in

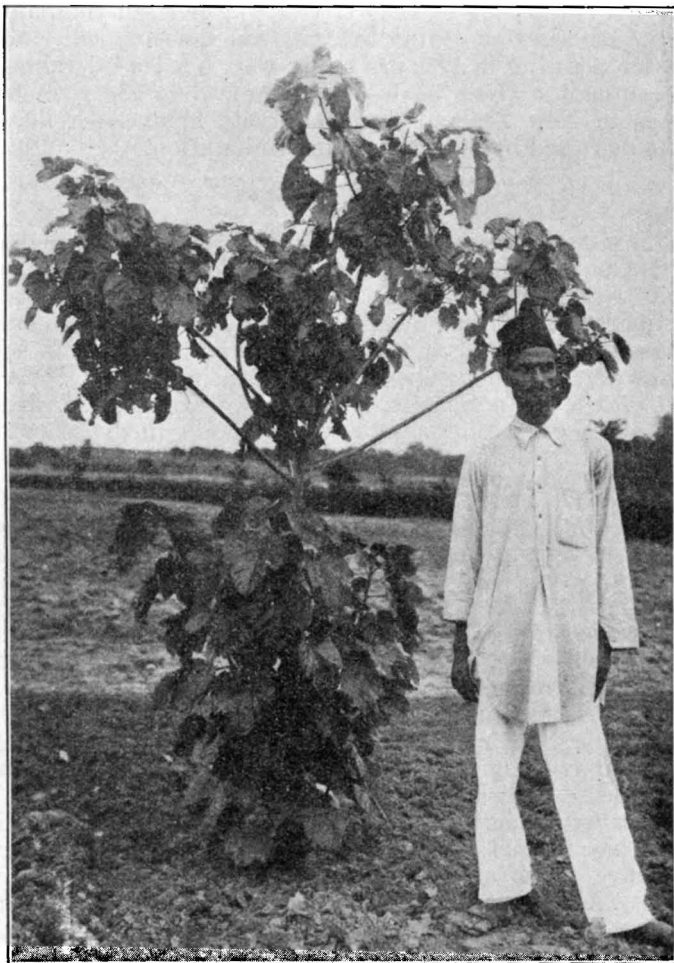


Figure 26.—Two-year-old tung tree in India

April, 1930, with a capital of over \$200,000, to engage in tung-tree estate development in the Northern Shan States. Sizable nurseries of both *Aleurites fordii* and *Aleurites montana* were initially established. At the close of 1931 nearly 720 acres had been cleared and planted at Hsum Hsai by this company, and further planting of 750 acres was contemplated during 1932.

CEYLON

The Ceylon Department of Agriculture reports that experiments with *Aleurites fordii* were initiated in 1917 and with *Aleurites montana* in 1923. Early plantings in certain sections of Ceylon, notably at Hakgala, Peradeniya, and Heneratgoda, were not particularly successful. Seeds, however, were later distributed to other districts and it was reported in September, 1929, that *Aleurites fordii* was enjoying a favorable growth in Etnawala, Ambepussa, planted in dry soil on an open hillside. Difficult conditions in the coconut trade since 1929 have created among private planters in Ceylon a greater interest in the possibilities of the tung tree. During 1930 and 1931 a considerable quantity of seed was imported from China and more experimental plantings were made. Most recent plantings have given better promise of success, but prospects are seemingly less favorable to large-scale development in Ceylon than in other countries in which experiments are being conducted.

MALAYA

The earliest experimental plantings of *Aleurites fordii* in British Malaya were made at the experimental station at Kuala Lumpur in 1914. Although these plantings showed favorable promise at the outset, they failed to develop satisfactorily and their cultivation was abandoned. The cultivation of *Aleurites montana* was undertaken in 1920 at Kuala Lumpur and later similar efforts were made on the Government plantation at Serdang in 1924. In general, trees of this more tropical species of tung tree showed a wide variation in their development, and fruit yields were very poor, considering the age of the trees. As a result of these trials it appears that both species are unsuitable for commercial cultivation on the plains of Malaya. However, further trial plantings are being carried out at the experimental plantation at Cameron's Highlands, at an elevation of nearly 5,000 feet, and it is possible that these efforts in the hill and mountain country of the Colony may prove more successful.

SOUTH AFRICA

The first experimental plantings of tung trees in the Union of South Africa were made in 1923 at Pretoria and Messina from seed obtained from the Imperial Institute. Although the percentage germination and growth of the trees were not particularly encouraging, additional consignments of seed were received from Florida, Australia, and England and distributed to Government experiment stations, individuals, and corporations interested in such experimental cultivation.

The best results up to the present time seem to have been obtained in east Transvaal, where plantings were made in 1928 at the Government experiment station at Nelspruit, at the gardens maintained by the division of plant industry at Pretoria and on the farm of Messrs. Banger and Allen, at Bushbuck Ridge. Banger and Allen report four hundred 3-year-old trees which are succeeding fairly well, although a variance of 1 foot to 5 feet 6 inches has been noted in the height of trees of the same age. The fruits so far obtained are being

used for further experimental plantings. A number of seedlings and young trees grown at Pretoria have been shipped to growers in other sections of South Africa.

Cultivation of the trees has also been attempted under official guidance in the Province of Natal by African Explosives (Ltd.), at Umbogintwini, and by the curator of the botanic gardens at Pietermaritzburg. African Explosives (Ltd.) reported from 50 to 71 per cent germination from several consignments of seed received, and experience with their plantings indicates that the trees should be planted out before they are 3 feet high and that cutting back should be reduced to a minimum.

Experiments made by the curator of the botanic gardens at Pietermaritzburg relate mainly to germination and transplanting practice. Low ratio of germination with seed received in 1927 brought about an investigation of planting seasons and means of preserving the seed. Sowing during the dormant season was one of the reasons for poor germination, according to trial plantings conducted. Seed received for planting was kept dry in powdered charcoal until September or October, the proper planting season in that locality. Tests were made as to the safe limit of disturbance from the nursery bed to tins or to permanent plantings. No loss occurred when plants were lifted toward the end of the dormant period, nor did loss occur from plants in tins put out during the growing season.

Plantings have also been reported in certain sections of Cape Province and Swaziland. The Rhodes Fruit Farm (Ltd.), of Groot Drankenstein, Cape Province, state that their cultivation of tung trees at Languedoc and Boschendal has proved fairly successful, and in the spring of 1931 they had 264 trees ready for transplanting. Seeds planted by D. R. Keith at Stegi, in east central Swaziland, in 1930 are growing well. One hundred and forty young seedlings were transplanted and only one was lost in the transfer from nursery beds. Tung trees have recently been planted at Magut, in the Pongolo Valley, where the expenditure of over \$1,000,000 on an irrigation project is contemplated.

It is estimated that at present there are approximately 2,000 trees in the Union of South Africa. Further extension of cultivation is being undertaken to establish more definitely the most suitable region in the Union in which *Aleurites fordii* can be grown and to stimulate business interest in large-scale planting of tung trees.

KENYA

Plantings in Kenya have recently proved more promising. Early trials with both *Aleurites fordii* and *Aleurites montana* at altitudes over 5,000 feet resulted in failure of seed to germinate rapidly, and growths were successful only at Nairobi, where two of the trees planted in 1922 and 1923 flowered and fruited. On account of difficulties of procuring good seed, the nut yields of those trees were retained for further planting within the country. Trial extraction by the Imperial Institute of some of the Kenya-produced seeds showed that the oil compares very favorably with the Chinese tung oil of commerce. Further efforts in experimental cultivation are being carried out throughout the Colony, and recently it was reported

that an important coffee planter in Kenya had planted 200 acres of his estate in tung trees.

CYPRUS

Results obtained from plantings in Cyprus in 1927 and 1928 were not very promising. Later plantings which survived the intense summer heat and cold winter winds in small nurseries were transplanted and thus far have shown fair development. The trees have not as yet matured sufficiently to afford definite evidence of their adaptability in Cyprus.

PLANTINGS IN LATIN AMERICA

The interest of governmental and private groups in certain Latin American countries have been aroused in the cultivation of tung trees as a result of the widespread publicity given to such efforts in the United States. Development in that area, which has been confined largely to plantings in Argentina, Paraguay, and Brazil, are described in subsequent paragraphs. It is known that seed has also been dispatched to Mexico, Nicaragua, Cuba, and Puerto Rico, but no definite information has been received up to this time relative to the success of adaptability trials in those countries.

ARGENTINA

Plantings of tung trees in Argentina, although still in an experimental stage, have shown rapid growth, and further interest is being manifested in more extended development in that country. The area most adapted to the planting of the tung tree in Argentina seems to be the Territory of Misiones, the Province of Corrientes, and the northern portion of the Province of Entre Rios. This region, bounded by the Uruguay and Parana Rivers, has a very rich soil, abundant rainfall, and a fairly warm climate. Attempts have been made to grow the trees in the Province of Santiago del Estero, but plantings have been injured there by nematode growth.

The first plantings were made in July, 1928, by the North Eastern Argentine Railway, from seed obtained from Florida. About 8,000 seeds were set out on the experimental farm of the railway at Pindapoy, Territory of Misiones. The trees flourished during the first year, ranging from 58 to 78 inches in height, and a number of them were transplanted with good results. The officials of the railway company are of the opinion that plantings will not prove of commercial importance unless carried out on a large scale, and more extended plantings are contemplated. Recent reports indicate that there are about 30,000 trees growing in the district near San Jose and Pindapoy, in the Territory of Misiones. Many planters have become interested, and it is estimated by the chief of the experimental farm of the North Eastern Argentine Railway that there were at least 50,000 trees on the estates in the Territory of Misiones at the end of 1931, judging from the amount of seed brought in and planted. The oldest trees to be found are nearly 3 years old and many of them have already produced good-sized fruit. Although up to date there has been no commercial production of tung nuts or oil, prospects for the commercial development of a tung-oil industry in Argentina are reported to be quite favorable.

PARAGUAY

Considerable interest has been manifested in plantings of tung trees in Paraguay during the past few years. The first seed was set out in the garden of the American consulate at Asuncion in December, 1928. Later, interest in further experimental cultivation developed and several hundred kilos of seed were obtained from the United States and distributed by John B. Faust, American chargé d'affaires, in lots of 500 to 2,000 to farmer-planters and public officials in various parts of the country. Small plants from the con-

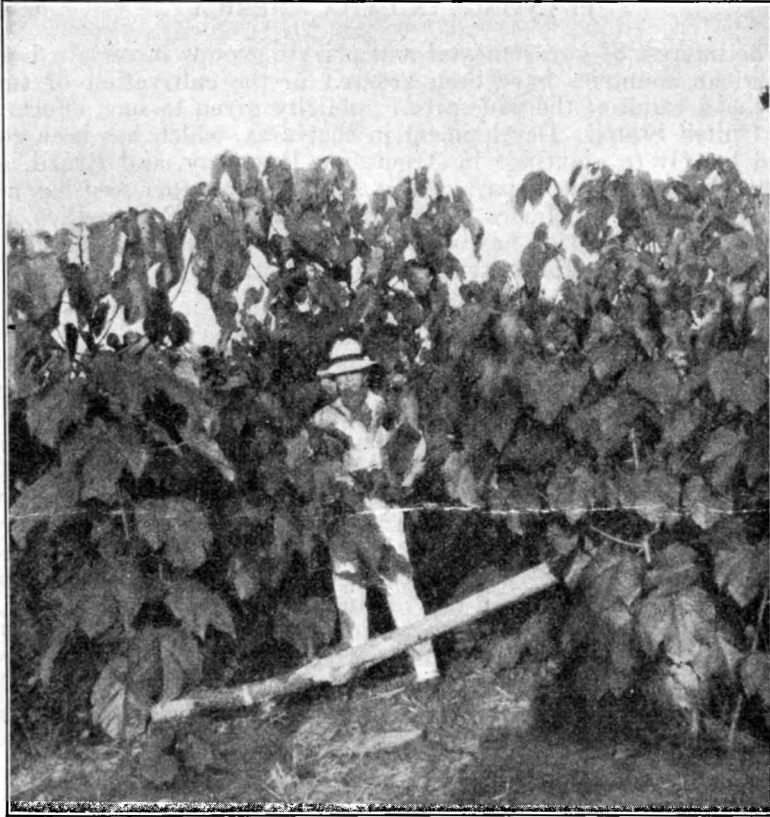


Figure 27.—Tung trees at Rosario-Loma, Paraguay, 10 months after seeds were planted in recently cleared woodland. These trees will be replanted at age of 12 to 13 months

sulate garden were presented to the President of Uruguay, the minister of foreign affairs, the supreme court judges, and to various other prominent men. The manager of the Paraguayan Central Railway became interested; he purchased seed direct from the United States and set out nearly 12,000 trees in the railway tree nursery at Sapucay. Present estimates report total plantings of more than 30,000 young trees in Paraguay during the past three years. According to present plans, the first crop of seeds obtained, which will probably appear in 1932 and 1933, will be used for further plantings. As

a result of the favorable growth of *Aleurites fordii* in Paraguay, it is claimed that future years may see the establishment of a tung-oil industry in that country, even though it may develop only as a side activity of small landowners, with commensurate volume of production.

BRAZIL

The agricultural department of the State of Sao Paulo, Brazil, is actively interested in investigating the possibilities of growing tung trees within that State. Arrangements were made in September, 1930, for the procuring of seeds through the Japanese consulate in Sao Paulo, which were to be distributed to estates and plantations in various parts of the State for planting. Although no report of actual plantings has been received as yet, agricultural authorities believe that the soil and climatic conditions in that part of Brazil will prove favorable to the germination and growth of tung trees.

CULTIVATION EXPERIMENTS IN OTHER REGIONS

Numerous trial plantings outside the British Empire and Latin America have been undertaken during the past few years. Although complete reports of progress in these experiments are not available, reference to but a few may serve to show the widespread and growing interest in tung-tree cultivation.

NETHERLAND EAST INDIES

The department of agriculture at Buitenzorg, Java, conducted experimental work during 1929 and 1930 in the growing of various species of tung trees. It was found that seeds of *Aleurites montana* obtained from South China grew more rapidly than those of *Aleurites fordii* received from the northern tung-oil districts of China. During the early months of 1931 experiments in grafting the two species were undertaken, in a hope to combine the rapid-growing quality of *Aleurites montana* with the reputed better oil quality of *Aleurites fordii*. The results of the grafting will not be evident for several years—at least not until trees bear fruit—although present reports indicate that the grafts are knitting nicely. In March, 1931, 150 pounds of seeds of the tung tree were received from the United States for test planting. Government authorities believe that tung oil can be produced on a large scale in most parts of the Netherland East Indies, and expect large plantings of the trees to be made as soon as experiments indicate the best species to cultivate.

MADAGASCAR

Madagascar plantings of *Aleurites fordii*, given little attention, have tended to disappear gradually. Recently, however, French forest-service authorities have recommended further experimentation, particularly with regard to the yield of oil from existing trees in that colony. If the oil produced is reported to be satisfactory, nursery establishment will be seriously contemplated.

OTHER PLANTINGS

In 1930 the National Fascist Farmer's Confederation became interested in the prospect of cultivating tung trees in Italy, and imported a consignment of seed for trial cultivation. A planter in Chimoio, on the Beira Railway in Portuguese East Africa, recently imported 3,000 tung-nut seeds for planting on his holdings. Shipments of American seed have also been dispatched to the Belgian Congo, Morocco, and Hawaii for experimental planting.

CONCLUSION

Tung oil is characteristic of the many important raw materials contributed by the Orient to the industries of the Occident. This product, employed crudely for centuries by the Chinese for various purposes which did not take full advantage of its valuable properties, was brought within a relatively short time to a position of prominence in international commerce by the vision, capital, and enterprise of the western world.

As has been mentioned previously in this study, venturesome spice traders first introduced the commodity into European markets during the sixteenth century, but early progress in the adoption of tung oil by industries of that continent was slow. The first appreciable shipment of the oil to the United States in 1869 marked the beginning of a substantial world trade in tung oil, to which development American industry has been an outstanding contributor.

Chemists and industrial technicians have eliminated a number of difficulties involved in handling the oil and have materially assisted in demonstrating the distinctive usefulness of this product. Thus, science has played an important part in the establishment of regular consuming outlets for the oil and in the continual amplification and diversification of its fields of application. The greater acceptance and more general use of tung oil in the United States than in other countries may be attributed in a large measure to the progressive spirit of American industries, manifested specifically in their pronounced research activities in the field of raw materials.

Expansion of world consumption has been reflected in the steady development of the Chinese export trade in tung oil. Improvements in transportation and communication have largely eliminated time and distance as trade obstacles. However, certain local conditions affecting production and supplies of tung oil in China, as well as the natural limitations and uncertainties associated with complete dependence upon a single foreign source of supply, have tended to restrict industrial reception of this commodity. These factors directed the thought of botanical specialists and industrial consumers to the possibilities of establishing tung-oil production in other countries.

Experimental plantings of *Aleurites fordii* throughout the world have resulted, and successful adaptation of the tung tree has been accomplished in a number of the British Dominions and Colonies, in Argentina and Paraguay, and in the United States. The United States has been the leader in these planting developments and now reports a total area of over 30,000 acres devoted to this oilseed crop. Plantings in several foreign countries are now approaching the large-grove development stage. In general, however, the growing of tung trees in regions outside the United States has been undertaken only in recent years, and has not as yet assumed commercial proportions.

Progress in the establishment of a domestic tung-oil industry has been most pronounced in the United States. A considerable extension of tung-tree acreage has been noted during the past year, particularly in Florida and Mississippi. Domestic production of tung oil, begun on a small scale with the establishment of a modern tung-oil mill in the South in 1928, has been gradually increasing and has been restricted only by the extent of bearing acreage and the rather general employment of nut yields for further plantings. The first shipment of a full tank car containing 65,000 pounds of domestic tung oil to consuming channels in the spring of 1932 is a very promising demonstration of the excellent prospect of developing commercial production of the oil in the United States during the coming years. The superior quality claimed for tung oil produced by machine expression will give domestic supplies of the oil an advantage in ultimately competing with imports from China.

Enthusiasm over the possibilities of the new industry is spreading rapidly, and many people unfitted to carry on planting activities, or interested primarily in real-estate sales or stock flotation, are now attempting to engage in the promotion of grove developments. The investor, therefore, should exercise care in investigating the organization, the motives, and stability of tung-oil development financing ventures, so as not to encourage unsound methods which may shake public confidence in a promising infant industry.

The value of permanently founding a tung-oil industry in the United States can not be measured only in terms of the saving of millions of dollars now expended in China for supplies of this commodity. The significance to southern agriculture of rapidly expanding commercial acreage devoted to a crop for which there is a large existing market in the United States can not be overlooked. As an agricultural activity, tung-tree plantings promise to benefit all classes of people in the South—bankers, property owners, foresters, farmers, and laborers. Plantings represent a splendid contribution to the diversification of agriculture in that region and provide a profitable use for large tracts of waste and uncultivated land. The milling phase of this industry will directly add to industrial activity in the Gulf States and will indirectly stimulate interest in the location of paint and varnish and other consuming industries near supplies of one of their most pertinent raw materials.

APPENDIX

A. CHINESE REGULATIONS FOR TESTING TUNG OIL

[To be executed by the Hankow Bureau of Inspection and Testing of Commercial Commodities and other official testing stations. Approved by Ministerial order No. 13939]

1. The following regulations are drawn up in accordance with the provision made in Article II, section 1, and Article XXI for the inspections and testing of commercial commodities.

2. All tung oil to be shipped abroad, for transshipment, for reexport, or for domestic marketing, whether in small containers (baskets, drums, or barrels), or in bulk (steamers or lighters) prior to the sealing of the containers or holds shall be subject to inspection. A blank testing form shall be filled out and the testing fee paid at the Bureau of Inspection and Testing of Commercial Commodities, in accordance with the regulations as set hereunder.

3. When an application has been received, the bureau will immediately send out its officer to take a sample according to the following method:

(a) For every shipment of 100 containers, or less than 100 containers, samples of one-half kilo of oil each shall be taken from four containers. For 50 containers or less than 50 containers, samples of 1 kilo of oil each shall be taken from two containers. Any amount over 100 containers shall be counted additionally in proportion.

(b) For oil in bulk, one-half kilo of oil shall be taken from each of the three sections, i. e., top, middle, and bottom of the hold.

(c) The sample oil thus taken shall be mixed together for a general average sample, out of which 2 kilos of oil shall be taken and placed in four vessels. The sampling officer shall seal and stamp the covers of the vessels, after which one shall be given to the applicant, one used for testing, and the remaining two kept at the bureau for retesting. Any surplus oil shall be returned to the applicant.

(d) Samples shall be taken only after the oil has been put in containers or loaded in lighters, and the containers from which samples are taken shall be stamped by the sampling officer.

(e) After samples have been taken, the sampling officer shall issue a receipt to the applicant.

4. The required standards for tung oil to be exported abroad are as follows:

Item	Maximum	Minimum
Appearance.....	Pale and clear.	
Specific gravity at 15.5° C.....	0.943	0.940
Acid number.....	8	
Saponification number.....	195	190
Refractive index at 25° C. ¹	1.520	1.5165
Iodine number (Wijs).....		163
Heating test, test tube (minutes).....	12	
Worstall's test (minutes) ²	7½	

¹ The minimum refractive index for tung oil exported to Europe and Australia shall be 1.5150.

² The cake should be dry and firm, and should crumble under pressure of spatula without sticking.

5. The testing of tung oil shall be completed within two days after the sample has been taken, Sunday and holidays excepted. In case of emergency, special arrangements may be made.

6. After the testing of tung oil, a certificate or an analytical report shall be issued to the applicant in exchange for the sampling receipt.

7. The tung-oil certificate issued to the applicant shall be effective for six months.

8. When the tung oil has been found to pass the required specifications, each hold of the lighter or steamer and each container shall be stamped where the oil has been sealed.

9. In shipping oil from A port to B port, if the oil has passed the required specifications at Bureau A, it shall be exempt from further testing by Bureau B, but the original certificate shall be presented at Bureau B, for identification and indorsement; otherwise the oil shall be subject to a retesting according to Article XIX of the Provisional Regulations for the Inspection and Testing of Commercial Commodities.

10. The inspection and testing fee for tung oil shall be at the rate of 10 cents (Chinese dollar currency) per picul. The number of piculs shall be based on the weight as set down by the customs for duty. The testing fee shall not be returned, whether the oil passes the required specifications or not.

11. Retesting of the oil shall be allowed within six months at the request of the applicant or buyer.

B. THE ORIENTAL OILS ASSOCIATION RULES FOR TRADING

The Oriental Oils Association includes in its membership the principal American importers of tung oil. It is considered, therefore, that trading rules governing a large share of the United States import trade in this commodity should be of interest to tung-oil buyers and industrial consumers.

RULE 1

SECTION 1. All sales of China wood oil by members of The Oriental Oils Association shall be made under a written contract embodying the rules of The Oriental Oils Association, signed by both buyer and seller.

RULE 2.—QUALITY

SECTION 1. The standard of quality shall be pure China wood oil of fair merchantable quality according to season's production at time and place of shipment.

SEC. 2. Moisture up to twenty-hundredths of 1 per cent is tolerable without allowance. Moisture up to 1 per cent can not be rejected, but allowance shall be made by seller for such moisture in excess of twenty-hundredths of 1 per cent at double the contract price, plus one-half of 1 per cent of the contract price. Moisture in excess of 1 per cent entitles buyer to reject delivery.

SEC. 3. Purity of oil is to be evidenced by certificate issued by the laboratories of either Robert A. Worstall, Charles V. Bacon, Curtis & Tompkins (Ltd.), or Laucks Laboratories (Inc.), determination to be made in accordance with the methods prescribed by the American Society for Testing Materials Tentative Standards of 1929 (p. 271-278), which cover all except moisture. For moisture determination, the Dean-Starke distillation method shall be used.

SEC. 4. Buyer shall have the right to call for reanalysis by authorized chemist of the Oriental Oils Association. Should second analysis confirm the first, the result shall be final. Should there be a disagreement in results, then a third chemist of the association shall make the final analysis. All analyses shall be based on samples drawn at time and point of shipment. All referee analysis expenses shall be paid for by the party at fault.

SEC. 5. Nothing contained in these rules shall prohibit the sale of special grades of China wood oil (at special prices), but the general terms and conditions and a signed contract embodying these rules shall apply to such sales.

RULE 3.—SAMPLES

SECTION 1. Sampling shall be done only by recognized samplers and/or inspectors. Unless stated to the contrary, the cost of sampling shall be for account of the seller. The buyer shall have the option of having a representative present at time of sampling. Official sampler shall draw one sample, to be divided into three parts, one to be submitted to the chemist for analysis, the remaining two to be retained under seal for 90 days.

SEC. 2. Sampling shall be from 10 per cent of packages, and samples shall be taken with a clean glass thief of sufficient length to secure a full core

sample. The point of the thief should rest on the inside of the package opposite the bung opening. The contents of packages shall be well agitated by the sampler prior to sampling.

SEC. 3. Samples of oil in tank cars shall be taken by thief vertically through the entire core in the center toward each end of the tank car within eight hours of the time tank cars complete loading.

SEC. 4. All samples shall be marked plainly for identification, stating quantity of the parcel (or tank-car number), number of packages sampled, barrel numbers sampled, method used, commodity, place, time, date, weather, by whom sampled, marks and range numbers, and any other specific data that special cases may require.

SEC. 5. All samples shall be sealed in such manner as to preclude any possibility of removing the cap without breaking the seal. At least 1 gallon must be drawn, and may subsequently be thoroughly mixed and distributed as desired. At least three 1-quart samples of each shipment shall be sealed.

SEC. 6. Only new, clean, 1-quart cans shall be used for official samples.

SEC. 7. All samplers shall retain a 1-quart sample for a period of at least 90 days.

RULE 4.—WEIGHTS

SECTION 1. Weighing under these rules shall be done only by recognized public weighmasters, approved or licensed by their local organizations. Weight certificates shall show package or tank-car numbers; shipping marks; gross, tare, and net weights; date and location of weighing; and such certificates shall be final.

SEC. 2. Weights at point of shipment in the United States are to be understood as governing transactions.

SEC. 3. Weights of tank cars are understood to be based on public weighmaster's certificate of Transcontinental Freight Bureau weights at the Pacific coast and railway track scale weights or hopper scale at other points. Tank cars shall be free and uncoupled at each end when being weighed.

SEC. 4. Landed weights shall be understood to be weights taken after discharge from vessel and within five days after tender has been made. All packages are to be in sound condition prior to weighing.

SEC. 5. Cost of weighing shall be for account of the seller. The buyer shall have the option of having a representative present to check the weights. The buyer may demand reweighing of oil purchased *ex dock* or *ex warehouse* if weight certificates are dated more than five days prior to time of tender.

RULE 5.—TARES

SECTION 1. Tares of oil in packages shall be the original marked invoice tare. In the event of tares being illegible, weighmasters may have access to the original weight certificate to determine the correct tare.

SEC. 2. The buyers or sellers shall be entitled to demand the stripping of 10 per cent of the packages, provided there be justification for believing tares to be excessive. The seller shall make allowance to the buyer for excess of super-tares on the following basis: Wood barrels if exceeding 4 pounds per barrel; steel or iron drums, if exceeding 1 pound per package.

SEC. 3. Any claim for excess tares must be made within 15 days after delivery. The actual tares of packages must be ascertained by removing the head and draining and wiping out the package thoroughly. The stripping must be done in a warm place. The seller has the option of having a representative present during the operation. The cost of stripping shall be at the expense of the party making the demand.

SEC. 4. The tares of tank cars shall be the actual weight of the empty tank car after being certified as clean.

RULE 6.—TENDERS

SECTION 1. If delivery or shipment is at seller's option within a stipulated period, seller may demand of buyer, upon seven days' notice, buyer's requirements and shipping instructions. If buyer fails to furnish seller with such requirements and shipping instructions at the expiration of this seven days' notice, seller may cancel contract or sell the merchandise for buyer's account, upon 48 hours' notice, holding the buyer for difference in value and all expenses.

SEC. 2. When a rejection is left uncontested by seller or is sustained as a result of arbitration, seller shall have the original contract period within which to tender other lots.

SEC. 3. Where oil is sold for shipment or delivery during a certain period, shipment shall be understood to be at seller's option unless stipulated to the contrary.

SEC. 4. Settlement of contracts shall be based on 375 pounds net per barrel. Tank cars of 60,000-gallon capacity, 45,000 pounds; 80,000-gallon capacity, 60,000 pounds; 10,000-gallon capacity, 75,000 pounds. Other packages based on the custom of the trade.

SEC. 5. When contracts are written "about," or "more or less," or words to that effect, the weight franchise shall be understood to be 5 per cent more or less at seller's option. Any excess or deficiency greater than 2 per cent shall be settled for at the market price or contract price at time of shipment at buyer's option.

SEC. 6. Any excess freight charges assessed by transportation company because of deficient loading of cars are for the account of seller.

RULE 7.—DELIVERIES

SECTION 1. Contracts for imported merchandise are based on United States tariff, customhouse, and railway classification in force at time of sale. Any change in such classification before delivery or the imposition or change in duty or government tax or freight rates shall be for buyer's account.

SEC. 2. Each delivery on account of contract shall be treated as a separate contract, except that if either party becomes insolvent, all deliveries called for in the contract may be closed out at fair market price at the option of the solvent party, on due notice.

SEC. 3. Deliveries ex dock or ex warehouse New York shall be understood to be within the free lighterage limits of the port of New York. Oil sold ex dock or ex warehouse is, unless stipulated to the contrary, at the risk of buyer as soon as warehouse receipt or delivery order is accepted by buyer.

SEC. 4. When oil is sold f. o. b., the official date stamped by the originating railroad on the bill of lading shall be considered the date of shipment. Notwithstanding shipped to seller's order, goods sold f. o. b. cars are at the risk of buyer from and after delivery to carrier at point of shipment and upon issuance of documents by carrier.

SEC. 5. Seller shall present documents covering shipment to the buyer prior to the arrival of shipment at buyer's destination. Should the merchandise reach destination before receipt of documents by buyer, seller shall be responsible for demurrage, car rentals, storage, and other charges resulting therefrom.

SEC. 6. If seller agrees to postpone delivery of any portion of oil beyond the 15th of the month succeeding the month specified for delivery and acceptance thereof, the price of such oil shall be increased by the addition of \$0.001 per pound for each month or fraction thereof (after the month specified for delivery and acceptance) that delivery is so postponed.

RULE 8.—CASUALTY CLAUSE

SECTION 1. In all cases seller shall not be responsible for nondelivery or delay of delivery resulting from the acts of God, from the elements, or from the action of governments, or caused by strikes, fires, explosions, floods, war, riots, insurrections or civil commotions, lockouts, perils of the sea, embargoes, contingencies in the course of oversea voyage or overland transportation. *Provided*, That seller must prove the direct operation of any alleged disabling circumstances and must notify buyer of the existence of such circumstances as soon as known to him.

RULE 9.—PAYMENT

SECTION 1. The terms of payment shall be net, cash (sight draft) against documents.

SEC. 2. The documents for oil, unless specified to the contrary, shall consist of one negotiable railroad bill of lading; public weighmaster's weight certificate; certificate of analysis (or letter of indemnity guaranteeing purity and ultimate production of certificate of analysis).

RULE 10.—SHIPMENTS

SECTION 1.—Shipments shall be interpreted as follows, effective as of the date written shipping instructions are received by the seller: Quick shipment, within 2 working days; immediate shipment, within 5 working days; prompt shipment, within 10 working days.

RULE 11.—ARBITRATION

SECTION 1. Disagreements and/or disputes, unless amicably adjusted, shall be settled by arbitration in New York on immediate demand of either buyer or seller. Both buyer and seller shall have the option of appointing one arbitrator and these two shall select a third. In all cases the arbitrators shall be accredited representatives or alternate representatives of members of this association or members of the American Paint and Varnish Manufacturers Association and shall take the oath of arbitrators as prescribed by the New York State laws governing arbitrators. They shall sit as a court to hear evidence as submitted either orally or in writing by either or both parties to the controversy. The arbitrators shall have the privilege of questioning all witnesses. All shall be under oath when giving testimony; or, in the case of submission of evidence in writing such evidence shall be sworn to before an official duly authorized to administer the oath wherever such testimony may be given. The decision by the majority of the arbitrators shall be final and binding on both parties.

SEC. 2. Fees for arbitration shall be \$25 for each arbitrator, to be paid by party adjudged in default.

RULE 12.—TANK CARS

SECTION 1. Tank cars shall be of approximately 8,000-gallon capacity unless stipulated to the contrary.

SEC. 2. Sellers' tank cars must be of standard make and be provided with heater coils, and must be in good order and condition at time of loading.

SEC. 3. Unless otherwise provided, tank cars should be supplied by seller. The seller shall have the option of naming the routing with the exception of the delivering carrier, which shall be at the option of the buyer.

SEC. 4. The buyer shall be allowed one diversion on tank cars while en route, but diversion beyond original destination and/or reconsignment after arrival at destination shall not be permitted without the seller's permission.

SEC. 5. The buyer shall unload tank cars without delay. In the event of detention of tank car by buyer for a period of over 48 hours or reconsignment without permission, the buyer shall be responsible for and pay the seller detention charges and/or rental charges for the use of the tank cars in accordance with the average renting value for the period of the preceding three months.

SEC. 6. The buyer shall respect the instructions of seller covering the return of empty tank car—returning empty tank car in accordance with seller's instructions and furnishing seller promptly with complete information.

SEC. 7. When the buyer furnishes tank cars seller must give buyer instructions for forwarding the empty tank cars in sufficient time to normally enable tank cars to reach destination in time for loading. In the event that the seller fails to furnish instructions in sufficient time or the buyer fails to so forward tank cars, liability shall attach to the party at fault, who shall be liable for all extra expenses incurred.

SEC. 8. Tank cars, whether buyer's or seller's, shall be furnished for loading clean and in a fit condition to receive the particular oil which is being loaded.

C. STANDARD SPECIFICATIONS FOR TUNG OIL

[Established by the American Society for Testing Materials]

Item	Maximum	Minimum
Specific gravity 15.5/15.5° C.....	0.943	0.9400
Acid number.....	8	
Saponification number.....	195	190
Unsapnifiable matter, per cent.....	.75	
Refractive index at 25° C.....	1.520	1.5165
Iodine number (Wijs).....		163
Heating test (minutes).....	12	

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