TUNG OIL: A NEW PLANTATION CROP*

Commercial Importance.—This oil was first introduced on a commercial scale from China into the Western world under the name of Chinese Wood Oil, over 30 years ago, and reached its greatest development during the war, when it was an essential ingredient of airplane paints and varnishes. Today it forms one of the most important export products of China. As all countries for their supply are dependent upon China there is a strong competition for this oil and the price has been maintained at a high level, notwithstanding the quality offered often being poor and sometimes adulterated.

Its unique properties as a drying oil render it indispensable for certain types of varnish in which tough water-resistant films of high gloss are desired. It is now also widely used as an ingredient of certain types of paint media and in the manufacture of electrical insulating varnishes. Other industries are also interested, for example, the linoleum industry.

The exports from China and their destinations are given in the following table :

Exported to:	Tons of 1016 Kg.					Value in 1000£				
	1924	1925	1926	1927	1928	1924	1925	1926	1927	1928
U. S. A.	37 324	42 029	32 144	34 066	44 062	2 339	2 438	1 705	2 099	2 375
Hongkong	4 402	1 728	3 186	7 957	8 252	188	71	129	295	336
Great Britain	3 179	2 297	2 896	2 660	5 945	195	129	157	161	321
Germany	4 719	3 778	2 738	3 228	2 553	291	215	148	196	138
Holland	474	619	927	3 429	1 537	29	36	50	207	83
France	978	847	1 193	815	1 024	60	47	65	49	55
Japan	708	358	457	391	473	44	19	24	23	25
Italy	365	265	225	327	335	23	15	12	20	18
Denmark	249	156	144	202	333	15	9	8	12	18
Belgium	157	159	198	205	136	10	9	11	12	7
Other countries	786	983	427	358	487	48	57	21	21	27
Total...	53 336	53 219	44 535	53 648	65 137	3 242	3 045	2 330	3 095	3 403

The home consumption should be very much more important than the export.

Prices show rather much fluctuation : 1924 from £70-95, in 1925 from £62-80, in 1926 from £60-85, 1927 from £75-100 per long ton (1016 kg.) London. In 1928 and 1929 prices were rather constant gradually slowing down from £80 to 70.

* By M. B. Smits in *The International Review of Agriculture*, Year XXII, No. 8, August, 1931.

Botanical aspect.—Tung oil is obtained from the seeds of *Aleurites Fordii* Hemsl. growing in central and western China. Another species, *Aleurites montana* E. H. Wilson, is found in south-eastern and southern China, northern Indo-China, Siam and Burma and yields an oil which possesses similar properties to those of tung oil. These two oils, often mixed, are exported under the name of Chinese Wood Oil.

Aleurites Fordii is a quick-growing small tree which occurs especially in the Yangtze valley, where it is grown on hillsides in land unsuitable for ordinary cultivation. Summers are hot and humid, winters relatively dry and slight frosts occur and snow may cover the high spots. For Itchang, in the centre of this part of the country, the following climatological data are available:

	Rain (mm.)	Temperature	
Spring (March-Apr.-May)	301	April	16·5°
Summer (June-July-Aug.)	515	July	28·5°
Autumn (Sept.-Oct. Nov.)	242	October	18·7°
Winter (Dec.-Jan.-Febr.)	71	January	3·5°

For *A. montana*, a quick-growing tree of large dimensions which is cultivated in the same way, climatological data from Canton and Hongkong may be used as an average.

	Rain (mm.) Canton	Temperature (C) Hongkong
Spring (March-Apr.-May)	613	21·5°
Summer (June-July-Aug.)	720	27·3°
Autumn (Sept.-Oct.-Nov.)	187	24°
Winter (Dec.-Jan.-Feb.)	143	15·7°

The presumption, therefore, is that *A. Fordii* is likely to thrive best in climates which are less tropical than those which favour *A. montana*. In the region between the Yangtsekiang and the southern provinces both species occur, *A. Fordii* dominating to the north and *A. montana* to the south.

Both trees are desiduous and shed their leaves at the commencement of the cold weather.

A. Fordii has a low-branching habit of growth. The flowers are produced before the leaves in drooping clusters. Each cluster is made up of one or more female flowers surrounded by male flowers, but usually there is but one female flower to the cluster. In America it is hoped to develop by selection a multiple cluster type, which may be expected to crop more heavily.

A. montana produces flowers after the leaves have been formed, the flower clusters being developed in the young wood.

The fruits also differ in some respects. Those of *A. montana* are pear-shaped, spotted and wrinkled, the fruits of *A. Fordii* being apple-shaped, smooth and not much spotted. The first species contains three seeds in the fruit, the second five.

Its culture in China.—Its culture is restricted to land unsuitable for other use, but as the steep hillsides of the Yangtse basin offer many small patches which may carry one or a few trees, the production still is very important.

The seeds are laid out in nurseries and this practice seems to be of importance for the ultimate results. As is known from experiments in other countries a large number of the seedlings are very weak and not of much value. This nursery practice enables the farmer to eliminate the poorest growers.

Sometimes a small grove is found on less steep ground. Here every tree usually gets 20-25 sq.m. room and yields are obtained of from 9,000 to 11,000 kg. of seeds per ha.

The fruits are harvested when not yet fully ripe. They are put into small heaps and covered with straw and grass. A fermentation process sets in by which the seeds are freed and are easily cleaned.

It is, however, supposed that this fermentation process is deleterious to the quality of the oil; in America an oil was obtained from ripe fruits without fermentation of higher quality and very much lighter colour.

Experiments in the United States of America.—Very soon after the war American consumers of tung oil realised the danger of absolute dependence on one source of supply. A period of high prices in 1923 caused the American Tung Oil Corporation to be formed, which started with a capital of 100,000 dollars as a co-operative effort among the members of the American Paint and Varnish Manufacturers' Association. This Corporation was not formed with the sole aim of making profit out of the growing of tung oil trees as a business, but primarily to demonstrate what could be done with tung oil trees as a crop in the hope of encouraging farmers to cultivate the tree on a large scale upon a commercial basis. Also it was thought that tung oil plantations on the less profitable sections of average farms in suitable localities might ease the lot of the farmers in the southern States who had suffered heavy losses with sugar and citrus growing.

A few tung oil trees had already been successfully grown in various parts of the southern States; the oldest of those trees was some fourteen years old at that time (1923).

The Corporation acquired land adjacent to the Agricultural Experiment Station of the University of Florida, about 270 acres. The first seedlings were planted out in the spring of 1924 and since then the work has steadily proceeded with ever-increasing confidence and indications of a successful outcome. By 1926—2,500 acres had been planted; 4,000 at the end of 1928, and about 5,000 at the end of 1929. In addition 500 acres have been planted in States other than Florida. In January, 1929, an oil mill was erected at Gainsville (Fl.) with a capacity of 1,000 lb. of seeds per hour.

A most important feature in the study of tung oil is the fact that it has always been liable to heavy adulterations. One of the most interesting points of attention about the American production is the prospect of securing a really pure oil. And apart from the question of adulteration, the Chinese methods of manufacturing the oil are so primitive that the oil is often much darker in colour and more variable in its characteristics than it need be.

It has been found that the American produced oil is superior to the imported oil. The Florida Experimental Station gives the following recommendations:

1. The best time to sow is the middle of February (under Florida conditions). About 60 days are required for germination, but great variation is found in germinating energy, particularly when the seed is old. Single seeds should be used, and not the whole fruits. The seeds should be planted 3-4 inches deep and from 8-12 inches apart in the nursery rows. These rows should not be less than 3 feet apart, to permit ample cultivation between them.

The nursery site should be moist but at the same time should have good drainage. Water-logging is fatal to the young plants and unduly dry conditions cause a severe setback.

Cultivation should be shallow.

2. After one year in the nursery the seedlings may be transplanted to the field, using the same methods as are used in transplanting fruit trees. After transplanting they should be cut back leaving a shoot 12-14 inches long.

Experience has shown that the mortality among transplants is 1-3 per cent. After the third year mortality is negligible.

3. It is recommended that trees should be planted 12½ by 30 feet; after the seventh year alternate trees should be removed giving a distance of 25 by 30 feet. In hilly country contour planting is to be recommended.

4. In Florida the fruits are allowed to ripen on the trees. When ripe they fall to the ground and are left under the trees until thoroughly dry. On a commercial scale the seeds are separated from the fruits by means of mechanical decorticators. The seed after removal of the husk can be stored in any dry place.

For seedling purposes the seed should not be removed from the fruit until immediately before sowing, and not carried over from one season to another.

In Florida trees of an age of 8 years are nearly 30 feet high with a spread of 28 feet. Some young trees commence to bear fruit in the third year though cropping on a commercial basis is not expected to commence until the fifth year. It is generally held that the trees will reach full bearing in their tenth year. The oldest trees in Florida are not more than 25 years and are vigorous.

Figures from a company at Gainsville for a garden of 30 acres with well-cared-for trees of 5-6 years of age are: in 1927—9,182 lb. of dry fruits; in 1928—16,421 lb.; in 1929—39,006 lb. At the end of six years there were, according to these figures, 1,300 lb. of fruit to the acre, yielding approximately 280 lb. of oil and, at a price of 15 cents per lb. an outside return of 42 dollars per acre.

A tree aged 20 years produced a crop of 250 lb. of fruits, which is equivalent to approximately 54 lb. of oil, giving 7 dollars per tree or 700 dollars per acre; if all these should yield as much.

The Florida Experiment Station reports that *A. montana* grows vigorously but comes later into bearing than *A. Fordii*. Both species being dormant in winter were not injured by a low temperature of 15°F (= −9·5°C.). Hybrids of both species have been secured by cross pollination, *A. montana* being used as the male parent. Fertiliser experiments were started with *A. Fordii*.

Experiments in Australia.—In New South Wales experiments were started by the Botanic Gardens at Sydney. There are some 1,000 trees now planted, at intervals since 1919. The first experiments were made in 1913; of these only one tree (*A. Fordii*) remained, which began to bear fruit after three years and yielded 1½ bushels in 1918.

The composition of fruits and oil is normal but no data on yields of commerical fields are available.

Prospects for tung oil production in New South Wales are regarded as very satisfactory, the trees developing very well and showing a vigorous healthy growth.

Considerable efforts have been made in New Zealand to establish this new industry on the Northern Island. A syndicate of local agriculturists has been formed to plant 2,000 acres under tung oil in the Helensville district. A nursery was started with a nucleus of 1,000 plants.

Another report shows that it was proposed to develop 8,000 acres in Auckland Province with *A. Fordii*.

The Queensland Forests Ltd., is energetically preparing to develop tung oil plantations in North Queensland. This company reported a vigorous growth, plants being 12 inches high at 3-4 months from the time of sowing.

Experiments in Malacca.—As the temperature in China during the growing season equals that of tropical regions, or is even higher, and the rainy season coincides with the high temperature, it seemed possible that the cultivation of tung oil trees would be possible also in the tropics. Moreover, the related species *A. triloba* Forst. (=*A. moluccana* Wild.) and *A. trispersma* Blanco are very common in the tropical part of Asia.

It was to be expected, however, that *A. Fordii*, coming from the northern part of China, would be the least adapted to tropical conditions.

The Department of Agriculture of the Straits Settlements and Federated Malay States started a first experiment in 1914, importing seeds of *Aleurites Fordii* through the Bureau of Plant Introduction of the U.S.A. in January of that year.

These seeds germinated freely and the resultant seedlings were planted at the Government Experimental Plantation at Kuala Lumpur. Although the plants showed considerable promise at the start after attaining a height of about 5 or 6 feet, their growth was completely arrested and they soon developed a stunted appearance which clearly indicated that this species was unsuited to cultivation under local climatic conditions. In March, 1924, over 10 years from the date of planting, the Argiculturist then in charge reported: "Only few plants of this species now remain and they are in very poor condition, although they have been well cultivated and manured. The trees average 5 feet in height, have very few branches and are practically devoid of leaves". The plants in question never showed any signs of flowering and their cultivation was eventually abandoned.

It is now intended to carry out further trials at the Cameron Highlands (Malacca) at an elevation of about 5,000 feet above sea level, but the possibility of success is regarded as doubtful since there is no definite resting period.

Two experiments were made with *Aleurites montana*. The first was started also at Kuala Lumpur in 1919 and the second at Serdang in 1924, both with seed from Hongkong.

The seeds from the first shipment showed a very good percentage of germination and the plants made vigorous growth at first, but after a time they became somewhat straggly and began to throw out numerous suckers near the ground. Measurements taken in 1923 showed that they ranged in height from 4 feet to 16 feet, while the girth varied from 6 inches to 14 inches at two feet from the ground. A few trees commenced to flower in January, 1924, but the majority of flowers did not set; only two isolated fruits were produced. Their cultivation was abandoned in 1926, the experiments having proved a complete failure.

The second consignment consisted of 735 seeds, giving about 45 per cent of germination in seed boxes. As they developed they were removed to small bamboo baskets and in March, 1925, they were planted at a distance of 20 feet by 20 feet.

After planting growth was fairly rapid. One tree commenced to flower in March, 1926.

A number of trees flowered during 1927 and a small quantity of seed was collected during that year. At the end of 1928 the majority of the trees had reached the flowering stage but only a small number were bearing fruit. The following is a record of the weight of cleaned nuts produced during the past three years from an area of approximately 3½ acres: 34 lb. in 1928; 30 lb. in 1929, and 68 lb. in 1930.

Flowering and fruiting occurs throughout the year but is more pronounced during the dry seasons January-February and July-August.

The records show that the weight and composition of the fruits is approximately the same as those of the seeds arrived from Hongkong. The composition of the oil also is about the same, the iodine value (Wijs) only being somewhat lower for the oil and somewhat higher for the fatty acids. The general behaviour of the individual trees is most erratic and specimens are to be found flowering, fruiting, and wintering at the same time, which may possibly be due to the absence of a definite resting period. It has also been observed that so far the number of female flowers produced is proportionately small.

It would appear that this species of *Aleurites* is also unsuited to the conditions prevailing in Malaya.

Experiments in Kenya.—As in Malacca experimental plantings of *A. Fordii* and *A. montana* have been established, the first originating from Hankow, the second from Hongkong. The results have been more promising than in Malacca. The seeds of *A. Fordii* were sown in August, 1922, at an altitude of 5,500 feet. Germination was poor and took 52 days. In May, 1924, the resulting plants were from 3-5 feet high and in a healthy condition. Other seeds were sown at 8,000 feet altitude; they germinated in 82 days; 12 of the seedlings were planted out, but in May, 1924, only one remained which was 9 inches high. Towards the end of 1923 more sowing took place at various altitudes from 5,000-8,000 feet. In 1926 it was reported that those planted at Nairobi in 1923 at 5,600 feet were in some cases 5-7 feet high, while others were stunted, being only 18 inches high. A few of those planted at 8,000 feet were still alive in 1926.

In February, 1928, the trees were fruiting pretty fairly freely. They showed, however, great differences in development, some being 10 feet high and others only 18 inches. Experiments made in Kenya, elsewhere than at Nairobi, were not successful.

The *A. montana* seed was sown in 1922 at Nairobi at an altitude of 5,500 feet. Germination took place in 56 days but was poor, only one plant surviving, which reached 18 inches in height by May, 1924. Further sowings took place towards the end of 1923 at various altitudes ranging from 5,000 to 8,000 feet. The germination was again poor and only a few plants remained. In September, 1926, only one plant was still alive and though healthy in appearance, the growth had been slow, it then being only 3 feet 6 inches high. This tree flowered for the first time in February, 1928. The fruits of the *A. Fordii* were very slow in ripening, having been nearly six months on the trees, all through the hot dry weather and the main part of the rains.

Composition of seeds and oil from Kenya fruits did not differ from the Chinese.

Experiments in other tropical countries under British Government.—In 1922 seeds of *A. Fodii* were imported into Tanganyika in the Morogoro district. From these seeds a certain number of fruit-bearing trees have been developed, which made it possible to distribute African grown seeds in 1927 among planters in Tanganyika and Kenya.

In 1917 growing experiments were started in India, Ceylon, and Burma, which were not successful in Ceylon, but more promising in North-west India and the northern part of Burma.

No data are published about these experiments.

In 1927 the Research Association of British Paint, Colour and Varnish Manufacturers purchased selected seed of *A. Fordii* of the 1927 American crop and distributed it to privately-owned farms and estates, Government agricultural stations and forest officers from Kenya to the Cape, and in Nigeria. A further distribution was made in 1928.

New experiments were started in the Nilgiri Hills, the Malwa Plateau of Central India, in Behar and Orissa, Bengal and Assam.

Seed was also sent to the West Indies. The results in Jamaica were negative.

Tung oil trees in Madagascar.—In 1902 Dubord reported in *l'agriculture pratique des Pays chauds* that an *Aleurites* growing spontaneously in Central Madagascar might be *A. cordata*, which is planted in Japan. An investigation of botanical material by Jumelle showed it not to be *A. cordata* but *A. Fordii*. According to Perrier de la Bathie this tree, in which nobody there takes an interest, is tending to disappear. It must have been introduced a long time ago, but the natives do not make much use of it. It bears fruit regularly and abundantly and the habit of the trees is healthy and strong.

Experiments in Java.—In 1835 Jacobson imported an *Aleurites* sp. of China into Java, but it is not known if it was *A. Fordii* or *A. montana*. The more probable is the former. At Buitenzorg the trees produced mostly male flowers. At an elevation of 3,000 feet trees developed less rapidly, but produced fruits at an age of 5-6 years. These experiments were not continued and no *A. Fordii* or *montana* is now to be found in Java, with the exception of some experiments which have been recently started.

Discussion of results.—It will be clear from the foregoing, that success has resulted from the experiments in Florida and in Australia and it seems that conditions are also favourable in central Madagascar. In Kenya results have been more promising than in other tropical countries but it is not possible to speak of a complete success.

From the conditions in the country of origin it may be deduced that the climate should provide a resting period for the trees.

Taking into consideration the climatic conditions of the central Yangtse basin and Southern China it seems that any intermediate climate should be favourable for one or both of the wood oil producing species; where the climate resembles that of Southern China conditions would be most adapted for *A. montana*, and where the data compare favourably with those of the Yangtze basin, *A. Fordii* may have the best chances.

Considering first the temperature conditions, we find (degrees C.):

	S. China	Yangtze	Florida	Sydney	Tananarivo	Ft.Smith (Kenya)
3 coldest months	15·7	3·6	12·9	12·1	13	14
Next 3 months	21·5	16·5	19·9	17 3	17·3	16
Following 3 months	27·3	28·5	26·4	21·6	19·2	17·1
Last 3 months	24	18·7	16·6	17 8	17·4	17

From these data it seems that temperature conditions in Florida and Sydney compare favourably with that part of China lying between the two mentioned. Next comes Central Madagascar, although temperature in the main growing season is about 9 degrees lower than in China. This difference is still larger in Kenya. It is, therefore, not improbable that the lower temperature of the high mountain plateau of Kenya is the cause of success not being complete.

Rainfall data are the following (total in 3 months in mm.) :

	S. China	Yangtze	Florida	Sydney	Tanana-rivo	Ft. Smith (Kenya)
3 coldest months	143	71	100	111	8	38
Next 3 months	613	301	101	74	68	72
Following 3 months	720	515	146	90	292	74
Last 3 months	187	242	105	134	89	215

Florida and Central Madagascar compare most favourably with China; Sydney and Ft. Smith show important alterations. When, however, temperature is of more importance for a resting period than rainfall, the better results in New South Wales may be explained thereby. Distribution of rainfall in Kenya, however, shows many irregularities, caused by the topography of the country. It is, therefore, not improbable that places may be found, which show a better combination of rainfall and temperature.

When we compare these data from places where the experiments met with more or less success, with those where only failure was met with, we see the following :

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
Colombo ...	26·1	26·5	27	27·5	27·8	26·9	26·7	26·9	26·9	23·6	26·4	26·2	Temp.
	82	48	121	290	307	212	113	97	127	365	319	161	Rain
Singapore ...	25·7	26·1	26·8	27·1	27·5	27·3	27·2	27	26·9	26·7	26·3	25·9	Temp.
	215	155	166	174	182	169	172	217	181	208	254	263	Rain
Buitenzorg...	24·9	24·3	24·7	25·2	25·2	24·9	24·5	25	25·3	25·3	25·1	24·6	Temp.
	449	408	422	412	374	277	265	227	345	420	395	373	Rain

These data show that temperature and rain do not provide conditions for a resting season. We, therefore, may presume that the wet tropics are not adapted for the growing of *A. Fordii* nor of *A. montana.* The best conditions are to be found in the wet sub-tropics.

If the results of the experiments in New South Wales remain satisfactory they may indicate the suitability also of the Mediterranean climate for the growing of these *Aleurites* species, which would be of enormous importance for the countries of these regions.

As, however, the *Aleurites* species prefer a soil with a slightly acid reaction, and in countries under Mediterranean conditions alkaline soils mostly prevail, much stress should be laid on the choice of the soil.

Chinese wood oil production in the wet tropics.—Although climatic conditions are not favourable in the wet tropics for the growing of *A. Fordii* or *A. montana*, there are other *Aleurites* sp. that are native to them. The most common is *A. moluccana* Wild. (*A. triloba* Forst.), known under the name of candlenut tree (Bankulnussbaum, Bancoulier). The seeds of this tree produce a drying oil (also known as *lumbang* oil) but of greatly inferior quality to the Chinese wood oil. When during the war supplies of linseed oil became scarce in Java, a substitute was found in this oil. As soon as normal supplies became available, however, this new industry vanished.

A far better quality of oil is produced by *A. trisperma* Blanco, native of the Philippine Islands, but also planted in Java. The oil of this tree seems to be used for adulteration of the Chinese wood oil. It is a good drying oil and is much used as a varnish and for caulking of vessels.

These species cannot of course be substituted for *A. Fordii* or *A. montana* as their products differ much from tung oil.

It seems, however, probable that they could provide a good base for hybridisation. By this process it might be possible to get a hybrid adapted to the wet tropics and producing an oil of the same qualities as the tung oil. As moreover, *A. moluccana* and *A. trisperma* grow more strongly than the Chinese species it is not improbable that the production of the hybrids would be larger. It is known that the different species of *Aleurites* cross readily. As it is also known that grafting or budding of *Aleurites* does not offer difficulties, it would be easy to propagate a valuable hybrid by using one of the tropical *Aleurites* sp. as stock