The Domestic Tung Industry Today

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Abstract

The tung tree (*Aleurites fordii*) requires a moderately acid soil, an annual rainfall of 45 to 70 in., and a long hot summer, yet it must have a period of cold weather in winter. These factors limit its culture in North America to a narrow belt along the Gulf of Mexico from Florida to Texas. The majority of the orchards presently consist of miscellaneous seedlings that are about 30 years of age. By replacing these with orchards of new varieties, on suitable soil, and by following recommended practices, growers can produce oil at lower costs than previously. However, crop loss from frost is still a serious problem. Machine harvesting is now a reality. During World War II the government requisitioned the entire domestic production of tung oil for military purposes, and regular customers had to turn to other products. This market has not yet been fully won back, and growers look to utilization research to improve the market.

Introduction

The tung industry of the southeastern United States originated out of a desire on the part of domestic paint and varnish manufacturers for a reliable supply of pure unadulterated tung oil and the need for a new cash crop for the South. The tung tree, *Aleurites fordii*, Hemsl., is native to China, and for many centuries the Chinese have used its oil to make lacquers and varnishes and for other purposes. Marco Polo first reported its use to the western world. In the late 1800's, when American manufacturers began to use the oil in quantity, China was the only source of supply. By the turn of the century, increasing adulteration of the Chinese product led to interest in a domestic supply.

Ecology of the Tung Tree

Potter (30) has described the rather exacting ecological requirements of the tung tree. It must have a long, hot summer and must also have 350 to 400 hours in winter when the temperature is 45F or lower. Warm winters limit its southern range. When fully dormant, temperatures lower than 6 to 8F are likely to cause extensive injury, and cold winter weather limits its northern range. It needs a well-distributed annual rainfall of 45 to 60 in. It also requires a slightly acid soil and pH no higher than 6.5; it is tolerant to considerably greater acidity. Since it is a crop that gives only a moderate return per acre, land must be available at reasonable cost. Alkaline soils, high land values, and prohibitive irrigation costs rule out its culture in those sections of California to which it may be climatically adapted. These factors limit culture of tung in the United States to a so-called "belt" lying approximately between 30° and 31° 30′ north latitude, extending along the Gulf of Mexico from northern Florida to Louisiana or possibly eastern Texas.

For profitable commercial production of tung oil, soil and topographic requirements must be more exactly defined. The tree is exceedingly sensitive to poor drainage. After thorough field and laboratory study Drosdoff (6) and Dyal and Drosdoff (8) concluded that good internal drainage and aeration are the most important requisites of a good tung soil. The physical properties of the soil must also be such as to store a large supply of available moisture. Drosdoff described the ideal tung soil as one having a sandy loam or loamy sand surface horizon, underlaid at 12 to 24 in. with a friable sandy clay, through which water will percolate readily and which tung roots can penetrate easily. Films of water on the soil particles provide the necessary water supply. Many soils of the area are considered excessively drained, but Neff et al. (24) have shown that tung can be grown successfully on rather deep, coarse-textured soils, provided that proper soil amendments are used. High fertility is, of course, desirable, but all tung belt soils are relatively infertile.

Topography is important because tung flowers appear in early spring and are subject to injury by frost. Frosts usually occur on still, clear nights when objects on the earth's surface lose heat by radiation into outer space. Air nearest the ground is cooled by contact with cold objects, becomes dense, and flows downhill as water would. Cold air collects in the valleys and bottoms. For this reason tung orchards are restricted to hills and slopes with lower land adjoining, with no barrier to air flow in between.

Establishment of the Industry

In 1904 L. S. Wilcox, consul general at Hankow, China, sent seed to the Section of Plant Exploration and Introduction at Chico, Calif. Fairchild (10) reported that, during 1906 and 1907, several thousand seedlings were sent to cooperators in the warmer sections of the United States. Several of those planted in the southeastern States grew well, and in 1913 officials of the National Paint, Varnish, and Lacquer Association produced the first American tung oil from the crop of a tree growing on the farm of W. H. Raynes near Tallahassee, Fla. In 1924 the Association itself planted a trial orchard near Paradise, Fla., and commercial plantings quickly followed. In the late 1920's planting spread to Mississippi and Louisiana, and by 1938 roughly 200,000 acres of tung had been planted in Florida, Georgia, Alabama, Mississippi, Louisiana, and eastern Texas.

Initiation of Research

In China tung is grown on marginal land, unsuited for growing food crops. A Japanese, Miyake (22), studied a leaf spot of tung in China as early as 1912, but otherwise little or no attention was given to tung culture. With its introduction to the United States, each of several state experiment stations issued publications on general culture: Newell (27) in Florida, Cochran (4) in Georgia, Hines (12) in Mississippi, Miller and Kimbrough (21) in Louisiana. Plant pathologists also were busy. Weber (41) published on thread blight, Boyd (1) and McCulloch and Demaree (17) on a bacterial leaf spot; in 1927 Plakidas (28) issued a comprehensive circular on diseases of tung. Some limited experiments on fertilization were conducted, and Mowry and Camp (23) saved the infant industry when they found that a disorder known as "bronzing" was a zinc deficiency.

Nevertheless funds were limited, and growers who had substantial investments at stake realized the lack of information and appealed for research by the USDA. In 1938 sufficient funds were made available by Congress to permit laboratory and field experiments on an extensive scale. The work was established in collaboration with the state experiment stations, particularly with the Mississippi Station. Large-scale field experiments were set up in approved, replicated field-plot design, and many were conducted in factorial design, which makes possible precise determination of the effects of each of several factors and at the same time any interactions between them. All results were analyzed statistically to determine their reliability before recommendations were formulated. Growers quickly found that they could get practical results by following instructions, yields were increased, and the cost of production per unit of oil was drastically reduced. It is safe to say that the industry could not have survived had the results of this research not been put into practice.

Improvement of the Tung Tree

Trees in the bearing orchards of 1938 were exceedingly variable in both quantity and quality of fruit produced. The tung tree is dioecious, producing pistillate and staminate flowers in the same inflorescence. The staminate flowers greatly outnumber the pistillate and surround them. Self-pollination generally takes place, but sufficient cross-pollination takes place to render tung trees heterozygous in varying degrees, and most trees produce diverse seedlings. However, on the basis of random chance, one may expect that occasionally self-pollination would take place for several generations, resulting in a fairly homozygous tree. The extensive line-selection project described by Potter (29) was immediately initiated, growers were consulted, and orchards were searched to find outstanding individual trees. These trees were evaluated, not on the basis of their own appearance and characteristics but on the relative merits of the progenies they produced.

Out of the hundreds of trees selected and tested, very few were found that produced uniformly productive seedlings of good commercial characteristics. From these trees the named varieties of tung described by Potter and Crane (31) were developed. After extensive tests conducted in representative areas of the tung belt, Merrill et al. (19) concluded that budded trees of these varieties have no advantage over seedlings for commercial planting. However most tung authorities recommend budded trees for seed production because they fear that growers using seed propagation generation after generation would not maintain the varieties true to type without deterioration. The superior yields of these varieties and the high oil content of their fruit have already done much to reduce the cost of production of tung oil. They are planted almost exclusively in North America but also in the tung-growing areas of Paraguay and Argentina in South America.

The present varieties are still subject to crop loss from frost. Efforts have been made to breed varieties less susceptible to cold damage both in the fall and in the spring by selection within the *A. fordii* species. An effort to develop a really late-blossoming variety was made by hybridizing *A. fordii* with *A. montana*, a species that blossoms later. This project was beset with difficulties from the start because *A. montana* is susceptible to cold in winter; also, it produces an oil of lower eleostearic acid content and the fruits have a woody hull that defies machine hulling. To transfer the late-blossoming character to hybrids that otherwise would have all or nearly all of the desirable commercial characteristics of *A. fordii* would be difficult under the best of circumstances. Furthermore Draper (5) has recently shown that, in the hybrids, cell divisions preceding seed formation are abnormal. For all practical purposes this reduces the possibility of developing a satisfactory, late-blossoming hybrid practically to nullity. Efforts are continuing to produce later-blossoming tung trees by breeding within the *A. fordii* species. Disease resistance is also being sought.

Cultivation

Tung trees are exceedingly susceptible to competition with weeds and grass. After plantings in a Norfolk fine sand soil near Ocala, Fla., had failed in successive years, Hamilton and Drosdoff (11) found that the growth of newly planted trees could be increased nearly fourfold simply by hoeing out grass and weed growth on the small area close to the tree that had not been reached in cultivating with a disk harrow. In further experimentation Drosdoff et al. (7) showed that the cultivation need not be deep; scraping off the weeds at the soil surface with a sharp hoe was almost as effective as spading. They also found that frequent early cultivation was most effective. After midsummer, hoeing did not do much good. Merrill and Kilby (18) and Neff and Potter (26) found that the same principles apply to fine-textured clay soils, and experience has demonstrated that the principles apply also to bearing trees.

The findings on cultivation have had a significant effect on spacing and planting systems in tung orchards. Most tung orchards are planted on the contour and are cultivated only along the row. With trees 20 or 25 feet apart in the row, control of grass and weeds is so difficult that growth is restricted and orchards are slow in coming into profitable production. When the trees are first planted, cultivation along the row with a one-way disk tiller controls weeds economically; and well-cultivated trees, set 10 feet apart in the row, quickly form a solid row in which shade controls most competing growth. Most growers now use close-planting distances in the row, adjusting the distance between rows according to individual preferences. The number of trees per acre now ranges from 110 to 140. Much greater early production is had than from orchards of 70 or 80 trees per acre, and yields at maturity are about the same.

Fertilization

In China the farmer and his family can harvest the tung crop even though it is small, but in the United States low yields would result in excessive harvest costs. Since all soils of the tung belt are relatively infertile, fertilization is required if satisfactory yields are to be had. Therefore tung nutrition has been studied intensively in controlled sand cultures, in extensive, well-designed field experiments located on representative tung soils, and by means of leaf analysis. The responses to individual elements has been determined with precision; it was also found that complicated interactions between elements exist and the application of one element may affect considerably the uptake and requirement for another. Sources of different elements, time of application, and placement of fertilizers were studied.

Some important relations between nutrition and cold resistance were observed by Shear (35) and by Brown and Potter (3). Symptoms of deficiency of several elements have been described. From the study of closely controlled experiments Shear et al. (37) evolved the hypothesis of nutrient element balance, and, with this in mind, standards for the nutritional status of tung trees have been set up in terms of leaf content of individual elements. For each element a range is given, within which the tree grows and fruits normally, provided leaf content of each of the other elements is within its "critical" range. These standards are helpful in making fertilizer recommendations, but, in using them, other criteria must also be taken into consideration. More than 100 papers have been published in the course of this research, and since space does not permit considering them in any detail here, the reader is referred to an excellent review by Shear (36).

As an example, effects of nitrogen, phosphorus, and potassium may be considered. In tung all pistillate flowers are formed in apical buds on shoots of the current season. These buds remain in an embryonic stage over winter and produce the crop the following year. Sitton (38) found that nitrogen increases the number of new shoots formed and the number of pistillate buds formed in each terminal. Since in tung practically every pistillate flower sets a fruit and fruit size is remarkably constant, yields in the year following the first application of nitrogen were increased in proportion to the number of flowers, often as much as 30%. However the nitrogen decreased oil content of the kernel and generally of the whole fruit. Potassium failed to increase growth and yield appreciably but did increase both percentage kernel in the fruit and percentage oil in the kernel, and this effect became more striking as year followed year. Eventually oil content of the fruit of trees that received nitrogen not well balanced with potassium became very low and the trees became susceptible to cold injury. Sitton found that tung requires a minimum amount of phosphorus fertilization, even on soil exceedingly low in native phosphorus content. This was fortunate because phosphorus is an expensive element. Most farm fertilizers are high in phosphorus, and fertilizer formulas had to be drastically revised for effective and economical use in tung orchards. Experiments similar to Sitton's were performed in other parts of the tung belt by Merrill et al. (20), Lagasse et al. (15), and by Neff et al. (25) with essentially similar results. In the eastern part of the tung belt, potassium in proper balance with nitrogen increased yields to some extent in addition to its effects on the oil content of fruit.

These results and other of similar nature made it possible to formulate fertilizer recommendations that had immediate and striking beneficial results. Effective fertilizer practice enabled growers to obtain highest yields at minimum cost and has been an important factor in putting the industry on a sound basis.

Other Research

Large (16) made exhaustive studies of the diseases of tung but found that for the most part losses do not justify control measures. The leaf spot first described by Miyake (22) tends to reduce oil content of tung fruit and in some seasons may cause losses of as much as 50 pounds of oil per ton of fruit. It was intensively studied by van der Zwet et al. (40), who found that it is best controlled by sanitation. The same practices that reduce infection with the leaf spot benefit the orchard in other ways.

When the tung orchard is three or four years old, only shade-resistant plants will grow in the tree rows. Oddly enough, one of these plants is the tung seedling itself. Another is the common wild blackberry. Control by hoeing is expensive and rather ineffective because plants hoed off will sprout again. Sitton and Lewis (39) have worked out economical and effective control with herbicides. Insects fortunately are not a problem. The leaves and fruit of tung are poisonous to animal life, and scale insects that seem to be able to thrive on tung are usually destroyed by their respective parasites and predators.

Tung fruit are allowed to drop to the ground and must dry out before being gathered and processed. Hand harvesting has been the rule for years, but after several years of research and development Jezek (13) now has a workable harvester. Machines are now manufactured commercially by two companies, and perhaps as much as 25% of the 1966 crop was machine-harvested.

Outlook

Most of the present tung orchards are nearing or have already attained 30 years of age. After extensive studies of the economics of tung growing, Powe et al. (33) estimated the profitable life of the tung orchard at not more than 28 years. Unless many of the old orchards are replaced, tung production in North America will soon decline rapidly. Even at support prices for the oil, many growers are able to make a profit and maintain that they know of no other cash crop that pays as well. A number of growers have initiated a program of annual replacement of a part of their acreage. Fortunately new tung plantings are thriving on land that had been in tung for 25 or 30 years. Some crops require rotation; peaches, for example, cannot be replanted on land previously in peaches. New land is also available. In some areas, as in southwestern Mississippi, nearly all the areas suited to tung production have already been planted, but, in the tung belt as a whole, much land remains that meets the rather exacting requirements. Production might be increased five or even 10 times if economic factors were favorable.

The research has done much to take the gamble out of tung growing. From now on tung will be planted only on suitable soils. Present tung varieties are not ideal but are infinitely superior to the miscellaneous seedlings found in all the old tung orchards. Present-day planting distances, culture, and fertilization make for earlier and higher yields. Terracing systems developed by Bregger and Brown (2) will conserve moisture and prevent erosion. Labor costs are constantly rising, but the principal use of labor is in harvesting, which may soon be largely done by machinery. The harvesters are costly, and only growers with large acreages can afford them, but custom harvesting will probably be available to the small-scale grower.

The most serious production problem yet unsolved is crop loss by frost. Potter et al. (32) studied the losses during the period 1939–56. Although minor losses in some localities occur about every year, in 11 of the 19 base years losses did not appreciably affect total national production. Using data of the crop reporting service, yields were plotted and a curve was drawn to fit the 11 years of no crop-loss. Percentage losses for the other eight years were calculated by comparison with this curve of total potential production and were found to constitute an average annual loss of 26%. Tung has a definite, biennial bearing cycle, and yields are above normal in years following a frost, as was the case in eight of the 11 base years. Thus the total potential production may have been over-estimated. Also many of the orchards are not well located with respect to air drainage. Taking these matters into consideration, Powe et al. (33) may be justified in assuming future losses to be about 20%.

Reducing losses by holding back the date of bloom with sprays or other treatments is still in the experimental stage, and, even if perfected, it may be difficult to put into practice. If Powe et al. are correct, one would have to spray five years to save one crop. Hope springs eternal in the human breast, and growers would be likely to take a chance on getting by without the expense of treatment. The real solution is in breeding a tree less subject to loss because of late-blossoming habit or inherent cold resistance. Tree breeding is a time-consuming process.

This brings one to a consideration of the market. The situation today is not bright, and the market study by Powe and Seale (34) is encouraging only in that they estimate the total annual potential market at 157 million pounds of oil. This seems astronomical in view of present usage but not when considered in the light of usage just prior to World War II. Wide variations in price have often made consumers reluctant to include tung oil in their formulations. Recently the National Tung Oil Marketing Association effected an agreement with the Commodity Credit Corporation in which the Association may use the CCC stockpile to overcome the gluts and shortages that have caused wide price fluctuations. Growers hope that this arrangement will give consumers greater confidence regarding the availability and price of oil. The growers of the United States and of Argentina have joined in supporting a utilization research laboratory and hope for a breakthrough that will substantially enlarge consumption. Taking everything into consideration, however, no one should embark upon a tung enterprise today unless, as Epperson (9) has pointed out, he can operate at high efficiency, and insofar as possible, mechanize operations according to the recommendations of Kilby and Jezek (14).

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