11-1-1964

Cultivation of tung for economic production, leaf spot reduction, spring frost protection

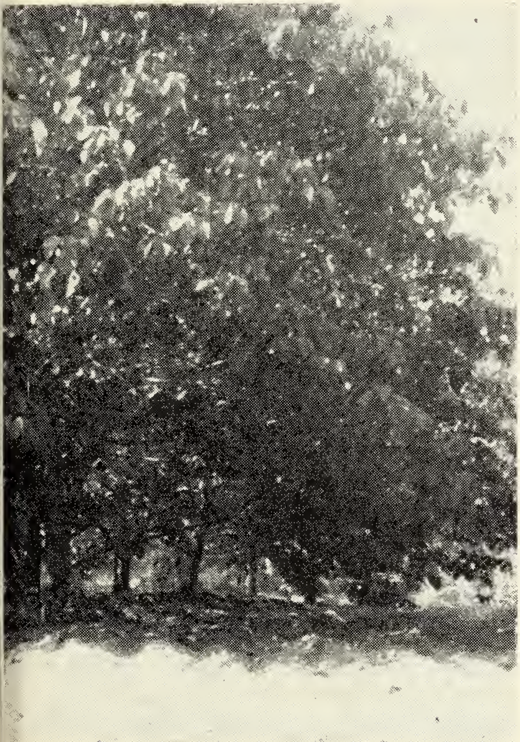
W. W. Kilby

C. B. Shear

T. van der Zwet

BULLETIN 696 NOVEMBER 1964

Cultivation Of Tung



for

Economic Production

Leaf Spot Reduction

Spring Frost Protection

by

W. W. KILBY, C. B. SHEAR,

T. VAN DER ZWET

Mississippi State University

AGRICULTURAL EXPERIMENT STATION

HENRY H. LEVECK, Director

STATE COLLEGE MISSISSIPPI

The Cultivation Of Tung

By W. W. KILBY, C. B. SHEAR, and T. VAN DER ZWET[1 2]

Soil type, orchard site, tree variety, planting distance, fertilization, and schedule of orchard management operations are all important considerations in the successful production of tung. No other single factor, however, affects growth, yield, and the general well-being of the tung tree so much as does cultivation.

Cultivation has three main purposes: to change the structure of the soil, to control weeds, and to manage crop residues. These effects of cultivation have many ramifications which influence many aspects of tung production. This paper will deal with cultivation as it affects growth and production of trees and the relation of cultivation to the development of the angular leaf-spot disease and to spring frost injury.

Growth and Production

Results of cultural experiments have demonstrated that competition from grass and other weeds greatly limits the growth of newly planted tung trees. The exact causes of the detrimental effects of weeds are still undetermined. There are a number of ways, however, in which weeds have been shown to adversely affect the tung tree. Weed roots, particularly those of grasses, are very fine and almost completely fill the upper 6 to 12 inches of the soil. Tung roots are much coarser and less prolific than grass roots and cannot compete with them. When conditions are favorable, fibrous tung roots concentrate in the top 6 inches of soil. Trees growing in a millet cover-crop, however, have been observed to produce only about half the quantity of fibrous roots that are produced by trees receiving good tillage (7). It was also observed on trees growing in 200-gallon cylinders of Lakeland fine sand, one-half of the surface of which was kept free from grasses and weeds, that the volume of tung roots was not only greater in the soil on the weed-free side but that tung roots that started out under the weeds grew toward the clean-cultivated side of the cylinder.

Competition for water and nutrients have been considered by many to be mainly responsible for the detrimental effects of weeds. Many experiments, however, have been undertaken to attempt to identify and evaluate the relative importance of the factors responsible for the effects of weeds on tung.

Merrill and Kilby (6) demonstrated that, even with adequate irrigation, newly planted tung trees that were hoed made significantly more growth and produced more branches than did trees left uncultivated. Unirrigated, mulched trees made significantly more growth than did unirrigated, uncultivated trees. These results indicate that conservation of moisture is important but is not entirely responsible for the beneficial effects of cultivation.

Drosdoff, et al. (1) compared effects on young tung trees of flat hoeing and cultivation to depths of 3 to 4 or 6 to 8 inches. They found no significant effects of depth of cultivation on growth and con-

---

[1]Respectively, Horticulturist, South Mississippi Experiment Station, Poplarville, Miss.; Research Plant Physiologist, and Research Plant Pathologist, Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, Bogalusa, La.

[2]The authors wish to make the following acknowledgements: Damon Palmer of the Soil Conservation Service, Purvis, Miss., for the photograph used in Figure 1; W. A. Lewis, Agricultural Research Technician, Crops Research Division, for preparation of photographic prints used in the other figures.

cluded that the removal of weed competition was primarily responsible for the beneficial effects of cultivation and that stirring the soil was unimportant.

Attempts to overcome the effects of weeds by supplying what were believed to be luxury levels of moisture and nutrients were unsuccessful in an experiment on trees planted in Lakeland fine sand in metal cylinders (7). In a similar experiment trees were grown in cylinders in Lakeland fine sand to which forced aeration was applied in addition to sufficient moisture and nutrients. With the addition of aeration, trees in Bermudagrass sod grew as well as did those kept free from grass. This finding of the importance of aeration for the growth of tung is in keeping with the common observation of the extensive development of tung roots in the surface soil, especially under trees casting dense shade, or where the surface of the soil is protected by mulch.

Growth and yield of mature trees also can be greatly reduced by weed competition. In an experiment at Agricola, Miss., (3), the effects on tung of a crimson clover cover crop plus 3 or 4 cultivations per year were compared with the effects of Bahiagrass sod with no cultivation. From the beginning of the experiment in 1957, through 1961, the trees growing in sod made only 75 percent as great an increase in cross-sectional area and produced only 88 percent as much fruit from 1957 through 1962 as did trees in the plots with cover crop plus cultivation. During the last 3 years of the experiment, as the detrimental effects of the grass accumulated, the trees in the Bahiagrass plots produced only 55 percent as much fruit as did those in the cover-crop-plus-cultivation plots (table 1). While exceeding the sod-grown trees in yield, the cultivated trees also were making more growth. Thus, one could expect the yield differences to become greater each year. After 4 years, the trees growing in sod showed much dead wood while those receiving cultivation did not (see figure 1). The trees growing in sod suffered much more winter killing in the severe winters of 1961-62 and 1962-63 than did the cultivated trees.

The competition between grass and tung for moisture often is dramatically demonstrated during drought periods. Trees growing in sod wilt much earlier than do trees in orchards which have been kept clean cultivated. The part of the growing season during which a moisture stress occurs will determine the nature and extent of its effects on growth and yield.

If weather conditions are favorable, shoot growth and fruit enlargement take place from April to July (2). Oil build-up in the fruit begins at about the time shoot growth and fruit enlargement cease, and flower-bud differentiation occurs during the same period (5).

Failure to conserve moisture by thor-

Table 1. Comparison of growth and yields of sod-grown and cultivated trees growing at Agricola, Miss.

Treatment	Growth increase cross-sectional areas of trunk (sq. inches) 1957-1961	Yields Tons/acre @ 15% moisture 1959	1960	1961	1962	Average
Crimson clover 3-4 cultivations	18.6	1.49	.96	2.48	.32	1.31
Bahiagrass no cultivation	14.0	1.27	.59	1.66	.13	.90
		N.S.	.001	.001	.001	

Figure 1. Comparison of cultivated and sod-grown tung trees. Trees in background were cultivated following crimson clover. Trees in foreground were in Bahiagrass sod. Note winterkilling on trees in sod.

ough cultivation during a dry spring may limit shoot growth, thereby limiting the number and area of the leaves which must manufacture the food required for oil synthesis and pistillate fruit-bud differentiation. Recent studies have shown that moisture stress during the period of oil synthesis also can reduce the oil content of the fruit. The importance of moisture conservation throughout the entire growing period thus becomes obvious, and clean culivation is the most effective and economical means of conserving soil moisture.

Angular Leaf Spot

Since the first serious outbreak in the summer of 1953, angular leaf spot has been the most serious disease of tung Even though the disease caused a serious reduction in oil content of fruit in 1956 and 1958 only, it remains a potential threat. Whenever the trees set a medium to heavy crop and the weather conditions during that season are favorable for development of the disease, leaf spot can cause a reduction of as much as 3 percentage units in the oil content of the fruit (17). Such a reduction amounts to a loss of 60 pounds of oil per ton of fruit, or $14.40 per ton with tung oil selling at $0.24 per pound.

The organism causing tung leaf spot is a fungus which completes its life cycle in two stages (14). During the summer, the parasitic stage **(Cercospora aleuritidis)** produces conidiospores on the angularly shaped leaf spots. These spores are the source of new infections throughout the growing season. When the leaves drop, the organism changes its mode of life and becomes saprophytic. During the late winter and early spring, fruiting bodies of the sexual stage of the disease organism **(Mycosphaerella aleuritidis)** develop in the spots on the dead leaves on the orchard floor. When conditions of temperature and moisture become favorable, the fruiting bodies discharge ascospores which cause the first infections on the newly developing tung leaves.

Studies by van der Zwet and Kilby (16) and subsequent observations have shown that, during and shortly after rainfall, ascospore discharge may start as early as the first of March and continue into August. The largest discharges, however, usually occur during March and April. Volunteer seedlings growing in the tree row, where concentrations of old leaves is especially heavy, become much more severely infected than do volunteers in the middles, where the old leaves have been destroyed by cutivation (15). These observations and preliminary cultivation experiments pointed toward thorough destruction of the old leaves through cultivation as a possible practical means of leaf spot control.

Kilby, et al. (4) reported that, in an experiment in which all leaves were removed from an isolated orchard by raking and burning, initial infection of volunteer seedlings did not occur until June 1, approximately 2 months later than on seedlings in commercial orchards. In May of the second year of the test, seedlings in the clean orchard had only 12.4 per cent of their leaves infected with an average of 5.9 spots per diseased leaf as compared with 43.6 percent infected leaves averaging 35.5 spots per diseased leaf on seedlings in an uncultivated orchard (19). Even though nearly 100 percent of the leaves on volunteer seedlings in both orchards were infected by the first of August, spots per diseased leaf on these volunteers averaged only 26.9 in the clean orchard as compared with 161.0 in the uncultivated orchard. In both years, the reduction in infection of mature trees resulting from clean cultivation still was apparent as late as September.

In another experiment, greenhouse-grown seedlings planted in cultivated plots had only 7 percent as many spots per leaf in July as did seedlings planted in uncultivated plots. On July 10, leaves on terminals of mature trees in the cultivated plots had ony 27 percent as many spots as did those on trees in the uncultivated plots, and by mid-August this figure had increased only to 50 percent (18). Figure 2 shows leaf-spot deveopment on volunteers in an uncultivated orchard in early June.

Though none of the sanitation experiments so far carried out has been subject to weather conditions conducive to severe leaf-spot infection, all the evidence accumulated indicates that thorough cultivation that will destroy most of the old leaves before ascospores have been discharged can be a significant factor in the reduction of leaf spot infection. The ultimate test of sanitation as an effective control for angular leaf spot must await the occurrence of an epidemic year for the disease. Nevertheless, significant reductions in the severity of the disease by thorough cultivation in late winter before leaves appear on the trees seem probable. Such cultivation, done annually, should progressively reduce innoculum to the point that, even in years when conditions are optimum for development of the disease, it may not become severe early enough to cause a reduction in oil content of the fruit.

Frost Protection

In 13 of the 26 years since 1939, late spring frosts have been responsible for losses ranging from 26 to 96 percent of the potential tung crop. With the exception of the freeze of March 27, 1955, which detroyed virtually the entire crop, damage has been scattered throughout the tung-producing area, and, usually, the losses have depended on differences in temperatures of less than 2 degrees F. Any practice which might prevent the temperature from dropping below the critical point for the buds at their stage of development at the time of exposure could, in many years, make a great dif-

Figure 2. Uncultivated orchard showing leaf-spot infection on volunteer tung seedlings. Photographed in early June. Compare with figure 5.

ference in the extent of crop losses in areas where the temperature was near the critical point for tung blossoms.

A number of methods for preventing loss of radiant heat have been used with varying degrees of success on many crops. These include the use of smoke blankets, wind machines, and sprinkling with water. None of these methods are feasible for tung. Artificial heating by methods such as the use of oil heaters is too costly to be practical for tung.

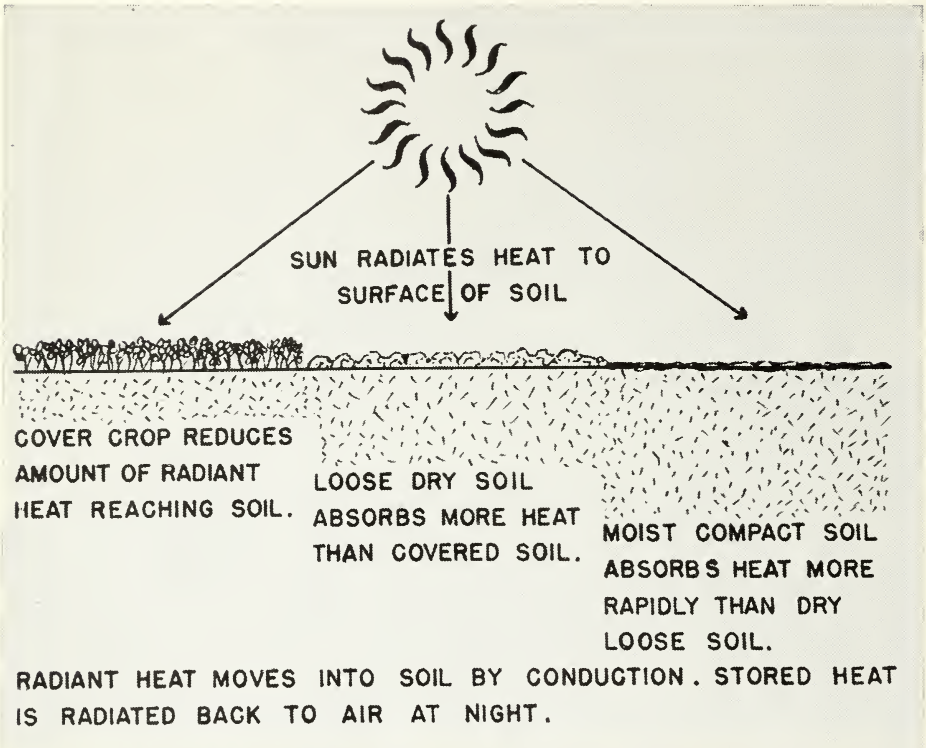


Figure 3. Proper preparation of the soil can create a reservoir for the sun's energy available as a source of heat to protect developing flower buds against radiation frosts.

The effectiveness of early cultivation in reducing damage to orchard crops from radiation frosts has been pointed out by many writers (8,9,10,11,12). A firm, clean-cultivated soil absorbs large quantities of heat on a sunny day (see figure 3). At the latitude in which most of the Tung Belt lies, approximately 224,840 BTU per acre per minute of radiant energy reaches the surface of the ground at noon on a clear day late in March. For the whole daylight period, the average is about 160,600 BTU per acre per minute, or 115,632,000 BTU per acre for the 12-hour period from 6:00 a.m. to 6:00 p.m.

Though color, texture, and moisture content greatly affect the rate of absorption by and release of heat from the soil, a clean-cultivated, dark-colored clay soil absorbs nearly 80 percent of the radiation that reaches its surface. A grass-covered soil, however, absorbs only about 65 percent. Thus, about 17,344,800 BTU per acre per day more energy is absorbed by clean than by weedy or trashy soil. Much of this radiant energy is stored in the soil, but on a night of high radiation, heat is lost from a clean-cultivated soil at the rate of approximately 1,000,000 BTU per acre per hour, or 12,000,000 BTU during a 12-hour night. This is more heat than is released in the burning of 2 barrels of crude oil.

On a clear, windless night following a sunny day, the temperature 4½ feet above a well-settled, cultivated soil will be 1 to 3 degrees F. higher than the temperature the same distance above a soil protected by a cover crop, grass, or mulch. The soil must be cultivated long enough before a frost to have permitted it to settle to a firm surface. A mulch of loose, freshly culivated soil can prevent absorption of radiant energy almost as effectively as a mulch of straw or weeds.

Thorough cultivation of the tung orchard 2 or 3 weeks before blossom time will put the soil in a condition to serve as an effective accumulator of radiant energy. Should the orchard be exposed to a radiation frost at the critical stage of bloom, this preparation of the soil may make the difference in temperature necessary to save the crop. Thus, what should be considered as a good orchard practice, regardless of the frost hazard, takes on the added value of frost insurance.

Obviously, a winter cover crop cannot be grown if early cultivation is practiced. Each grower must weigh the fertilizer and forage value of a cover crop against the advantages of clean cultivation for frost protection and reduction of leaf-spot infection.

Cultivation Machinery and Techniques

Machinery to be used in the tung orchard should be purchased wisely, with specific operations in mind. The cheapest or most readily available type of disk or harrow may do an unsatisfactory job in the orchard and, in the long run, be a poor investment.

Most tung orchards are planted on rolling terrain and, therefore, should be planted on the contour. In such orchards, the trees should be planted on the contour rows but not on top of prepared terraces. For the first 2 years after planting, disking should be done with a one-way disk (see figure 4) so that the soil will be turned toward the tree row. This will develop each tree row into a terrace having a gentle slope from the tree row to the center of the middle (see figure 5). In this way, good erosion control and drainage will be obtained and, at the same time, a gently sloping terrace with a broad base will be developed. Such a terrace can be cultivated easily and is well adapted to mechanical harvesting.

Care should be taken not to develop the terrace too high or too steep. In orchards newly planted in old cultivated fields, some hand hoeing in the tree row may be necessary the first year or two to satisfactorily control weeds.

After the terrace has been developed, a standard off-set disk should be used for subsequent cultivations (see figure 6). The front section of this disk cuts the soil away from the tree row, and the back section lays it back in place so that there is little or no displacement of the terrace. The middles may be cultivated with either an off-set or a tandem disk (see figure 7). A tandem disk should not be used along the tree row, however, as it will bar off the tree row, exposing large roots and eventually flattening the terrace (see figure 8).

The above described deep, row-to-row cultivation should be done in late winter so that all trash, old leaves, and vegetation will have been turned under and the soil had ample opportunity to settle before tree growth starts. This is essential if maximum benefit toward frost protection and leaf-spot control is to be realized from the cultivation.

When new growth of grass and other weeds begins in the spring, a wide, flexible spring-tooth harrow will do an adequate job of cultivation (see figure 9). This implement not only will destroy the weeds but will tend to level out any irregularities in the terraces. The spring-tooth harrow has a distinct advantage over a disk for summer cultivation in that it does not cut off surface feeding roots but tends to move them in the soil as would a comb, resulting in a minimum of

Figure 4. A one-way disk should be used to build terraces along the contoured tree rows in young orchards. By adjusting its pitch, this implement can be used to maintain these terraces after they have been formed.

Figure 5. Clean cultivated orchard properly terraced. Compare with figures 2 and 8.

Figure 6. An off-set disk can be used to cultivate close to the tree row without de stroying the terrace or barring off as shown in figure 8.

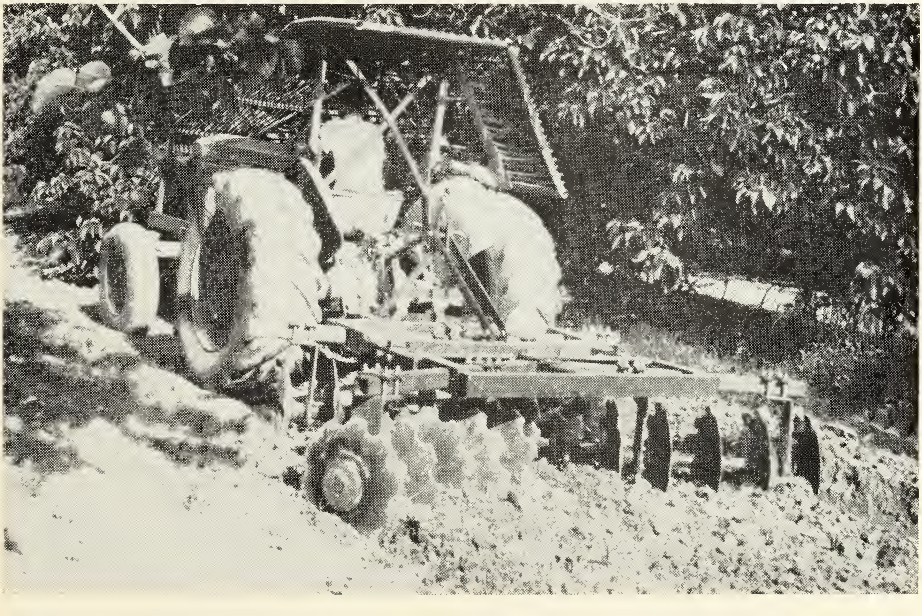


Figure 7. A wide tandem disk can be used to turn under old leaves and weeds in the middles.

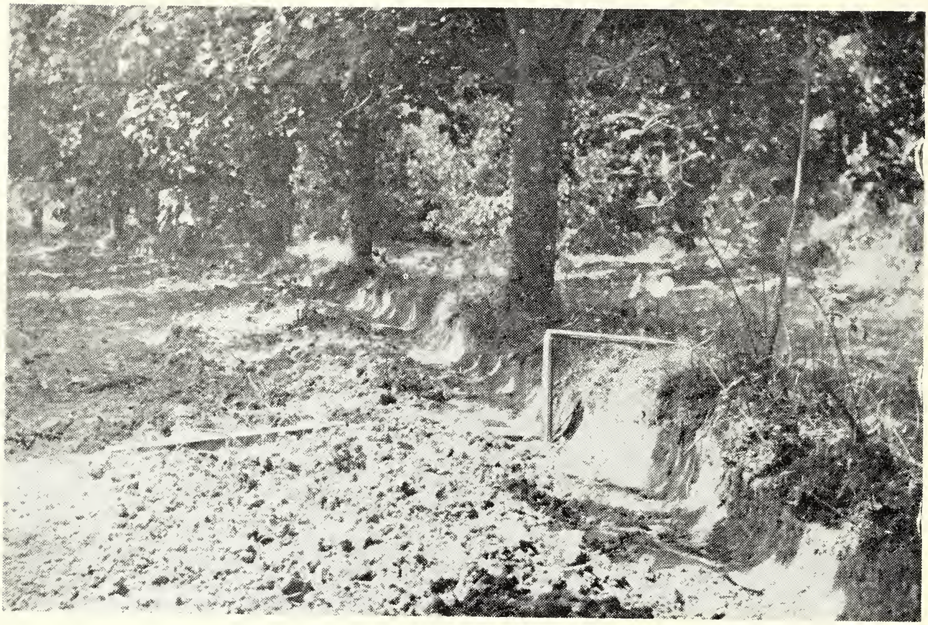


Figure 8. Tree row barred-off and terrace flattened by continued use of off-set or tandem disk along the row. Compare with figure 5.

Figure 9. A spring-tooth harrow will maintain a weed-free orchard during the summer if spring cultivation has been thorough. This implement is less destructive to tung feeding roots than is a disk.

damage. During prolonged dry periods, the harrow may be used to maintain a loose surface soil which will act as a dust mulch and greatly reduce loss of subsoil moisture.

Since the draft of the spring-tooth harrow is considerably less than that of the disk harrow, a much wider spring-tooth may be used on the same tractor which pulls the smaller disk. Thus, about two cultivations can be done with the spring-tooth for the cost of one with the disk.

The smoother the surface of the soil after the last cultivation in late summer, the more efficiently the harvesting can be done. A smooth surface is essential for mechanical harvesting, and hand harvesting will be done more rapidly and more completely in an orchard with a smooth surface. A chain-link harrow (see figure 10) does an excellent job of smoothing the surface when used on freshly harrowed or otherwise loosened soil. A log chain stretched between the rear corners of the chain-link harrow will smooth out any furrows left by the teeth of the harrow.

Finer textured soils prepared in the above-described manner will generally become firm enough to prevent the tung fruit from sinking in when they drop at maturity. In very sandy soils, however, the last operation in late summer should be the use of a heavy roller to compact the surface.

In contoured orchards which cannot be cross-cultivated, tung seedlings, briars, and other weeds develop between the trees in the row. The most efficient and permanent method of eradicating these weeds is to spray them with the herbicide 2,4,5-T. A formulation containing low volatile esters of 2,4,5-T should be applied at a concentration of 3 pounds of acid equivalent per 100 gallons of water. Spraying should either be done as soon as briars are in full leaf or after new canes have produced sufficient foliage to

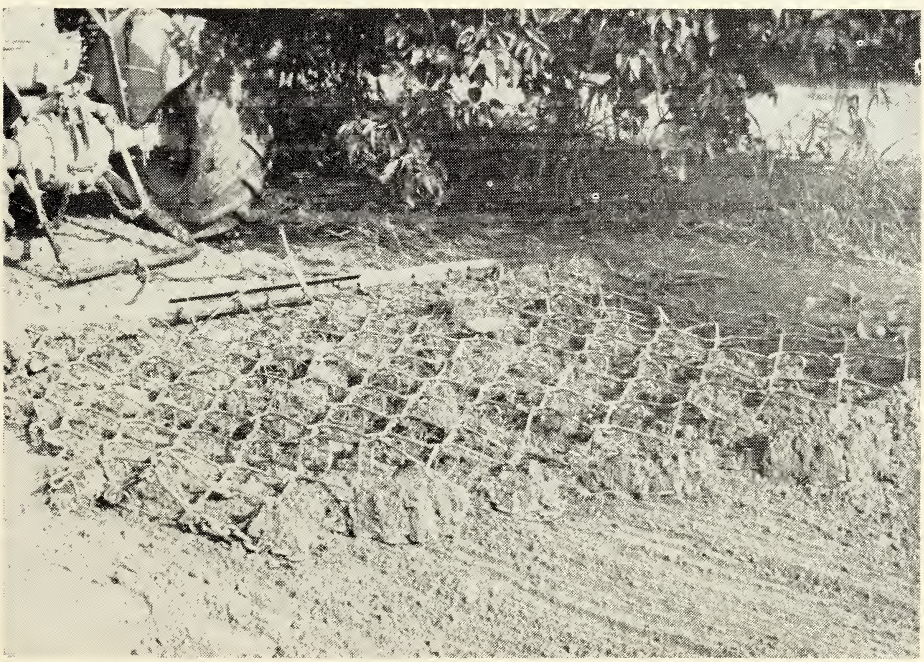


Figure 10. A chain-link harrow does an excellent job of smoothing freshly harrowed soil.

absorb a lethal dose. The best period is during May and June. Detailed instructions for spraying have been described by Sitton and Lewis (13).

The importance of clean tree rows must be emphasized. A thorough job of harvesting cannot be done, either by hand or machine, if tree rows are grown up in briars and volunteers. Such undergrowth also traps leaves which cannot be turned under with normal cultivation and, therefore, remain as a source of leaf-spot inoculum.

Timely and effective use of the proper cultivation equipment will pay greater returns on the money spent than will any other single orchard practice. In fact, much of the value of other cultural procedures, especially of fertilization may not be realized if cultivation is neglected.

RECOMMENDED CULTIVATION SCHEDULE

Newly planted orchards

Keep contoured tree rows free of weeds and construct terraces with one-way disk. After desired slope has been developed (second or third year), an off-set disk should be used to maintain terraces.

Mature bearing orchards

In late February or early March, turn under all old leaves and weeds with off-set or wide tandem disk. This cultivation prepares the soil for fertilizer application, reduces leaf-spot innoculum, and prepares the soil for optimum heat absorption and release for frost protection.

After bloom, cultivation with a spring-tooth harrow should be sufficient unless weed growth is rank enough to require a second disking.

The schedule of subsequent cultivations with a spring-tooth harrow will depend on conditions for weed growth. Weeds should not be allowed to develop to the extent that disking is required.

The last harrowing before fruit fall should be followed with a chain-link harrow to prepare the orchard for harvesting.

LITERATURE CITED

1. Drosdoff, M., E. G. Fisher, and J. H. Lassiter. 1947. Effect of frequency and method of cultivation on the growth of one-year-old tung trees. Proc. Amer. Soc. Hort. Sci. 50:115-118.
2. Kilby, W. W., and M. D. Parker. 1941. The growth period in shoots and fruits of mature tung trees. Proc. Amer. Soc. Hort. Sci.. 39:161-163.
3. ____________, and B. G. Sitton. 1961. Effects of varying levels of fertilization and cultivation on production and returns from the tung orchard. Proc. Tung Industry Conv. 28:8-9.
4. ____________, T. van der Zwet, G. F. Potter, and W. A. Lewis. 1961. Progress made on control of tung leaf spot. Miss. Farm Res. 24(11):7.
5. McCann, L. P., W. S. Cook, and C. R. Campbell. 1941. Factors affecting time of initiation and rate of development of pistillate flowers of the tung tree. Proc. Amer. Soc. Hort. Sci. 39:157-160.
6. Merrill, S., Jr., and W. W. Kilby. 1952. Effect of cultivation, irrigation, fertilization, and other cultural treatments on growth of newly planted tung trees. Proc. Amer. Soc. Hort. Sci. 59:69-81.
7. Neff, M. S., and C. B. Shear. 1956. Grasses, weeds, and tung trees. Proc. Amer. Tung Oil Assoc. 23:27-28.
8. Potter, G. F. 1954. The frost problem in tung orchards. Proc. Amer. Tung Oil Assoc. 21:28-29.
9. ____________, and H. L. Crane. 1951. Practical frost protection for tung orchards.. Amer. Tung News 2(4):4-5,9-10.
10. ____________, and ____________. 1956. Reducing the hazard of frost in tung orchards. Proc. Amer. Tung Oil Assoc. 23:23-26.
11. Rogers, W. S. 1952. Some aspects of spring frost damage and its control. Internatl. Hort. Cong. Rept. 13:941-947.
12. Shear, C. B. 1963. Practices that reduce frost damage in tung orchards. Proc. Tung Industry Conv. 30:28-30.
13. Sitton, B. G., and W. A. Lewis. 1962. Chemical control of briars, volunteer tung seedlings, and other broad leaved weeds in the tung orchard. Proc. Tung Industry Conv. 29:29-30.
14. van der Zwet, T. 1960. The life cycle of the tung leaf spot fungus, **Mycosphaerella aleuritidis**. Proc. Tung Industry Conv. 27:19-20.
15. ____________. 1961. Significance of the ascigerous stage of **Mycosphaerella aleuritidis** in the primary infection of tung in 1960. Proc. Assoc. of Southern Agri. Workers 58:219.
16. ____________, and W. W. Kilby. 1962. Determination of the dispersal of ascospores of **Mycosphaerella aleuritidis**. (Abstr.) Phytopathology 52(1):31.
17. ____________, and ____________. 1962. Influence of seasonal conditions on the development of angular leaf spot of tung. Proc. Tung Industry Conv. 29:26-28.
18. ____________, ____________, and W. A. Lewis. 1964. Effect of orchard sanitation on development of angular leaf spot of tung. Proc. Assoc. of Southern Agri. Workers 61:268-269.
19. ____________, W. A. Lewis, and W. W. Kilby. 1962. Progress in the experimental control of angular leaf spot of tung. Miss. Farm Res. 25(6):6.