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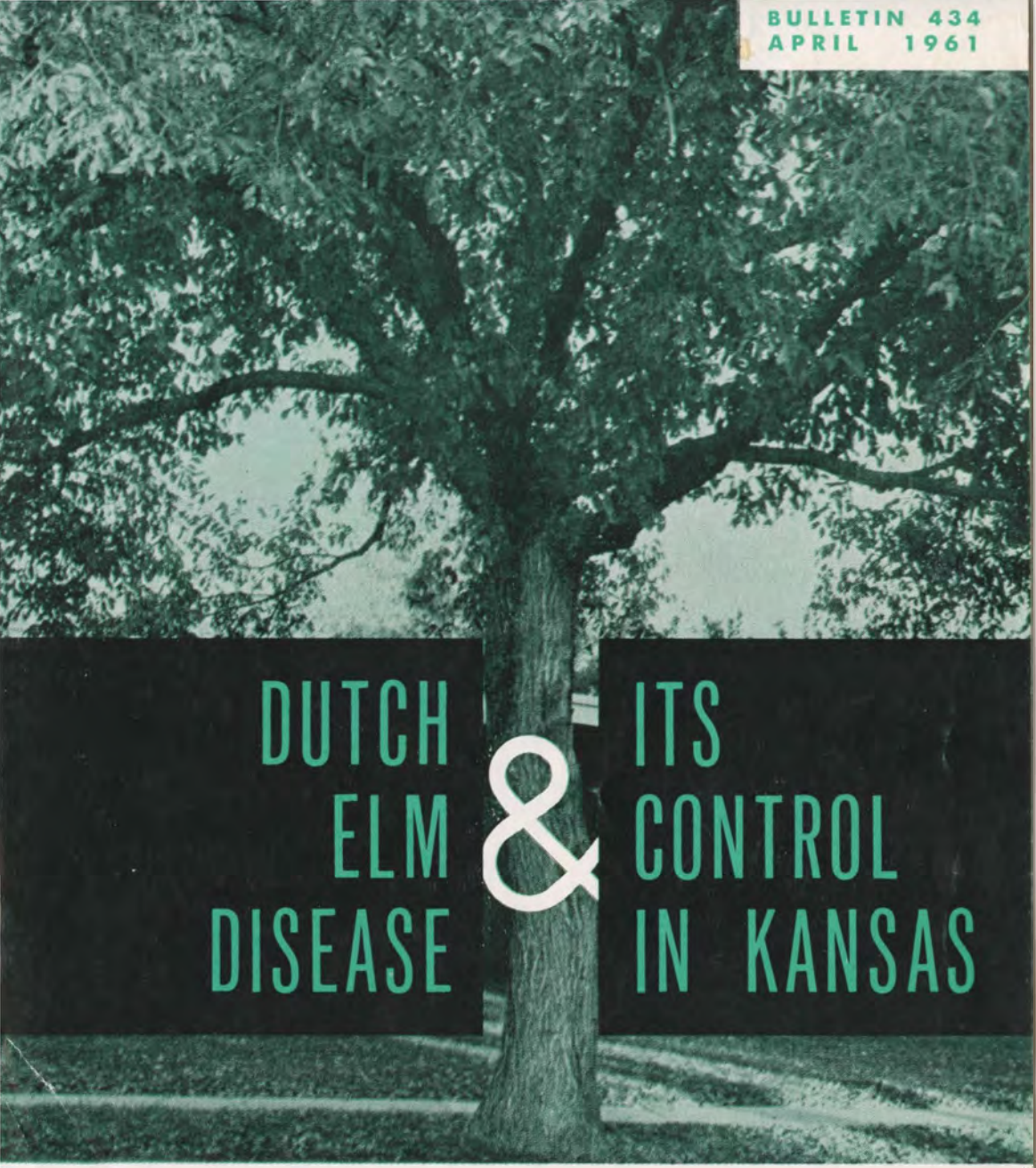

DUTCH ELM DISEASE & ITS CONTROL IN KANSAS

AGRICULTURAL EXPERIMENT STATION

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Dutch Elm Disease and Its Control in Kansas [1]

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INTRODUCTION

Dutch elm disease was discovered in Kansas in October, 1957, in Kansas City, Kan., and has been spreading rapidly since then. This information was prepared because the disease attacks American elm, an important shade and ornamental tree. The disease is caused by a fungus that is carried from elm to elm by bark beetles. Control measures are aimed at destroying the bark beetle. Although the control procedures recommended will not completely prevent the spread of Dutch elm disease, a community program including all phases of control will reduce the annual loss of elms to a reasonable level.

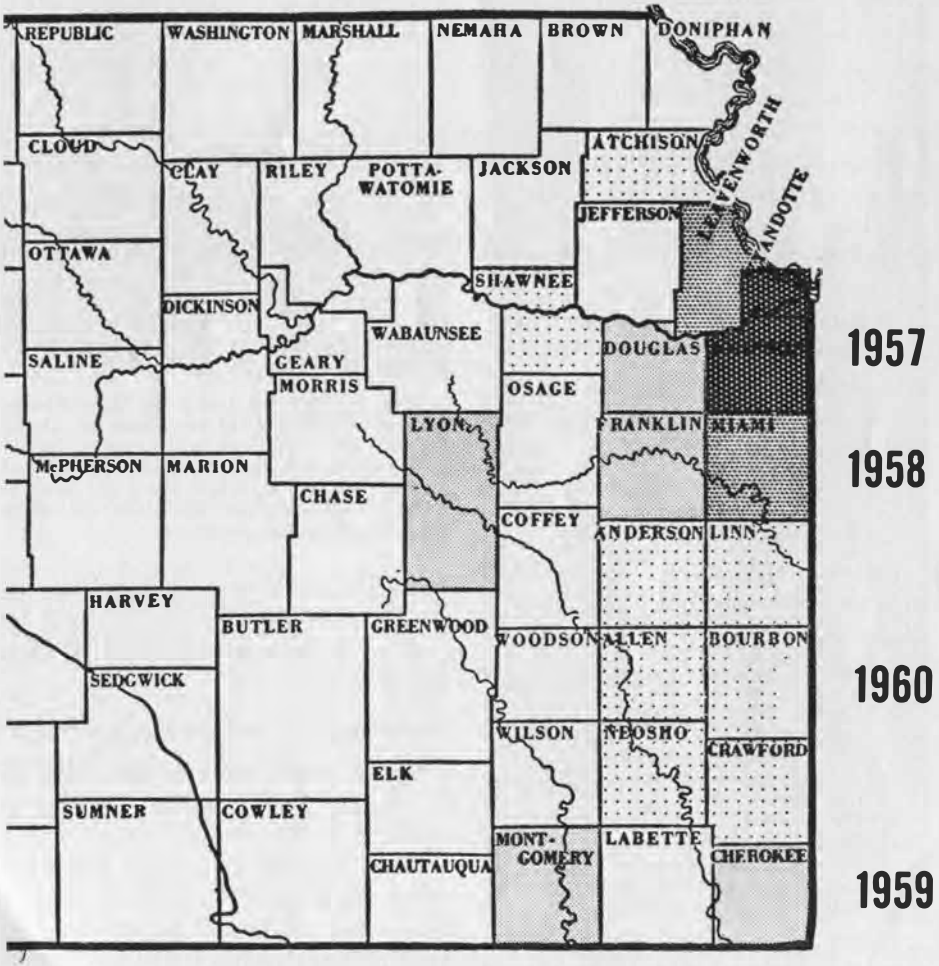

Fig. 1. Map of known locations of Dutch elm disease in Kansas.

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History of the Disease

First described in Holland in 1921, the disease marched across Europe in 10 years. In 1930 it was found on four dead trees in Cleveland, Ohio, and by 1933, in New York, New Jersey, Connecticut, Pennsylvania, and Maryland. By 1957 it was found in Kansas City, Mo. Three positive collections of the disease were made in Wyandotte and Johnson counties, Kansas, in October, 1957. In 1958 it was found in Leavenworth and Miami counties; during 1959, in Franklin, Douglas, Lyon, Cherokee, and Montgomery counties; during 1960, in Atchison, Anderson, Allen, Bourbon, Crawford, Linn, Neosho, Shawnee counties (Fig. 1). There is every indication that the disease is rapidly increasing in the eastern third of Kansas. It is present from the Atlantic coast west to Kansas, Nebraska and Oklahoma, and from eastern Quebec and Ontario to the southeastern states.

Symptoms of the Disease

Dutch elm disease is impossible to identify positively by sight, but its symptoms include:

a. Many dead branches on a tree or a portion of a tree.
b. Leaves wilting, frequently turning yellow or brown, and falling off early (Fig. 2). (Note: Other diseases, drouth, and bark beetles also may cause this.)
c. Weak growth of new branches.
d. Brownish coloring of outer rings of the wood. (Occasionally this symptom does not appear; also, other diseases may cause browning.)

Pieces of suspected elms are cultured in a laboratory to determine if the Dutch elm disease fungus is present. The fungus also may be isolated from beetles and tunnel debris. A tree dying with beetles present is not proof of the disease. Where the disease is unknown, the fungus must be isolated to be sure the tree died from Dutch elm disease.

Fig. 2. Infected tree near Osawatomie, Kansas, shows typical symptoms of Dutch elm disease. The limb in the center already is dead; the left limb has wilted leaves and partial defoliation, while the right limb is wilting. The disease has since spread to the elms in the background.

Life Cycle of the Fungus [5]

Dutch elm disease is the result of an unusual partnership, a beetle working with a fungus (Fig. 3) that parasitizes elm trees but does not harm the beetles. The beetles carry fungus spores from infected wood to healthy trees. After the spores are introduced into the tissues by the beetles, infection occurs.

Three kinds of infectious spores

5. *Ceratocystis ulmi* (Buis.) Moreau.

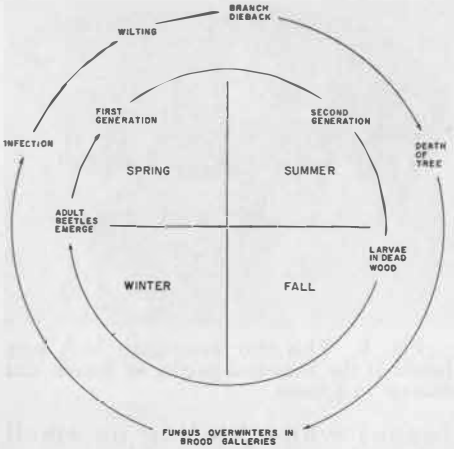

Fig. 3. Seasonal relationship between life history of the smaller European elm bark beetle and Dutch elm disease.

cause Dutch elm disease[6] but only the first two are important in the U. S. Both grow in dead elm wood, and particularly in the tunnels made by the beetles. Spores stick to beetles and can live on them 3 months at 10-20° C. and for 2 years in fresh frozen beetles.

Infection takes place only through wounds made by bark beetles in May (Fig. 4a). Healthy bark does not become infected. When beetles leave infected elm wood and fly to healthy elms, they carry the spores with them. As they burrow into the bark and wood, the spores are deposited in the tissues of the tree and immediately start to grow. The fungus develops rapidly and grows into the bark, the cambium, and the wood. When the fungus is present in the large vessels of spring wood, spores are produced and carried rapidly up into the branches where they infect new wood and cause it to turn a brownish color (Fig. 4b). A limb may wilt and die or the entire tree may die suddenly (Fig. 2). The fungus continues to live in dead trees and bark beetles continue their tunneling. The fungus grows and sporulates especially in its Graphium stage with its sticky masses of spores (Fig. 5). In May when the beetles emerge they carry the spores to healthy trees and infect them. Later beetle emergences are

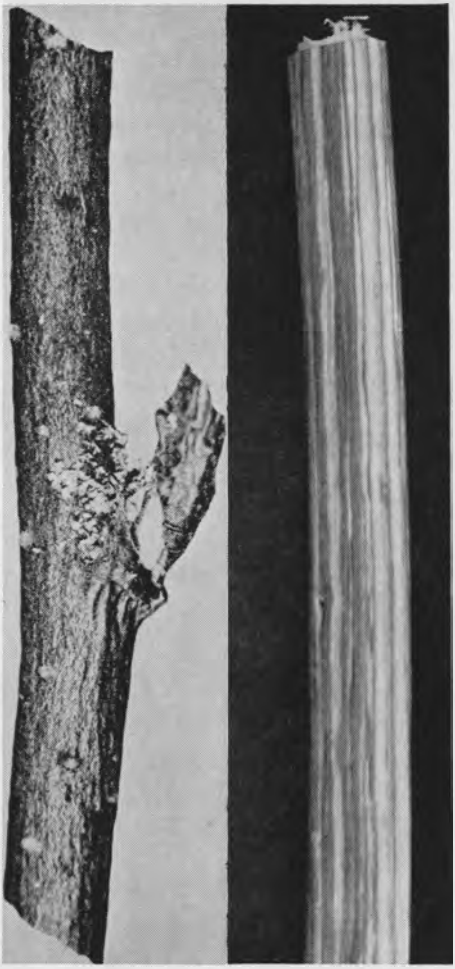

Fig. 4a (left). Beetles feeding through wounds such as this, introduce the Dutch elm disease fungus into healthy tree. (Courtesy of Dept. of Entomology, Cornell University.)

Fig. 4b (right). Infected sapwood becomes discolored around the infected sap-conducting vessels.

6. These are referred to as the Graphium, Cephalosporium, and Ceratocystis stages.

Fig. 5. Spore-bearing heads of the Graphium stage of the Dutch elm disease fungus growing in an elm bark beetle tunnel.

Fig. 6. This tiny one-eighth inch long beetle is the principal carrier of Dutch elm disease in Kansas.

less likely to cause infection because summer wood has covered the large vessels of the spring wood.

Besides being a vigorous *parasite,* the Dutch elm fungus can live saprophytically on dead elm tissues (Fig. 3). This means that once it kills a tree, it may survive from 6 to 12 months in dead wood and occasionally for 2 years.

It is important to recognize that *beetles may carry the spores to dead elm logs and trees* and these may harbor tremendous populations of both beetles and spores. Dead elm wood is thus like an arsenal with ammunition (spores) and missiles (bark beetles).

How the Disease Spreads

Dutch elm disease in Kansas is spread by the smaller European elm bark beetle[7] (Fig. 6) and the native elm bark beetle.[8] The smaller European elm bark beetle has almost eliminated the native elm bark beetle in Kansas during the last 10 years.

The habits of the two species of bark beetles differ, but the way they infect healthy trees is the same. Spore-bearing beetles introduce the fungus while feeding on small branches and twigs of healthy trees. Then they go, taking fungus spores with them, to weakened or dying trees to breed. Trees weakened by drouth and disease are especially attractive to bark beetles. They attack such trees, tunnel through the bark to the surface of the sapwood, and thus infect them with spores. Dutch elm disease also spreads by root grafts. Roots from adjacent elm trees form natural unions through which the fungus passes.

Life Histories of Elm Bark Beetles

The smaller European elm bark beetle produces three generations each year (Fig. 7). In September, adult females lay eggs in maternal galleries (Fig. 8). During the fall, after the eggs hatch, the larvae develop in the tunnels they bore under the bark. Late in the fall, as full grown larvae, they tunnel out into the outer bark, make a round cell, and spend the winter there. Early in April the larvae transform into pupae, and late in April the adults begin tunneling out. As soon as they emerge, they fly to nearby healthy elms and feed in twig crotches.

In a few days they finish their feed-

7. *Scolytus multistriatus* Marsh.
8. *Hylurgopinus rufipes* Eichh.

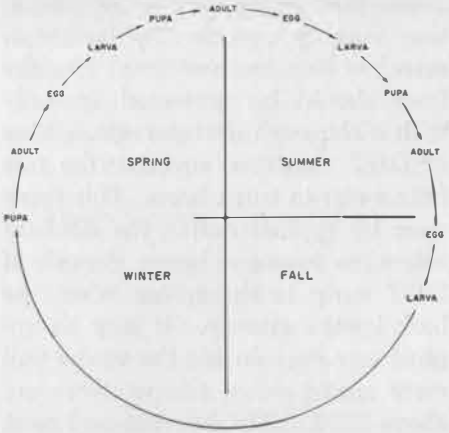

Fig. 7. Life history of the smaller European elm bark beetle.

ing and fly to dying or weakened elm wood in which they construct new galleries and lay eggs. This generation emerges as adults early in July. A third complete generation emerges in mid-September. It is larvae produced by this generation that overwinter under the bark.

The life history of the native elm bark beetle is more complex but similar to that of the smaller European elm bark beetle. Native elm bark beetles leave fungus-infected breeding wood in the fall and overwinter as spore-bearing adults in the bark of healthy trees. In late April, these adults tunnel to the sapwood where the spores are deposited.

Sanitation

Since beetles spread the fungus from infected to healthy wood by

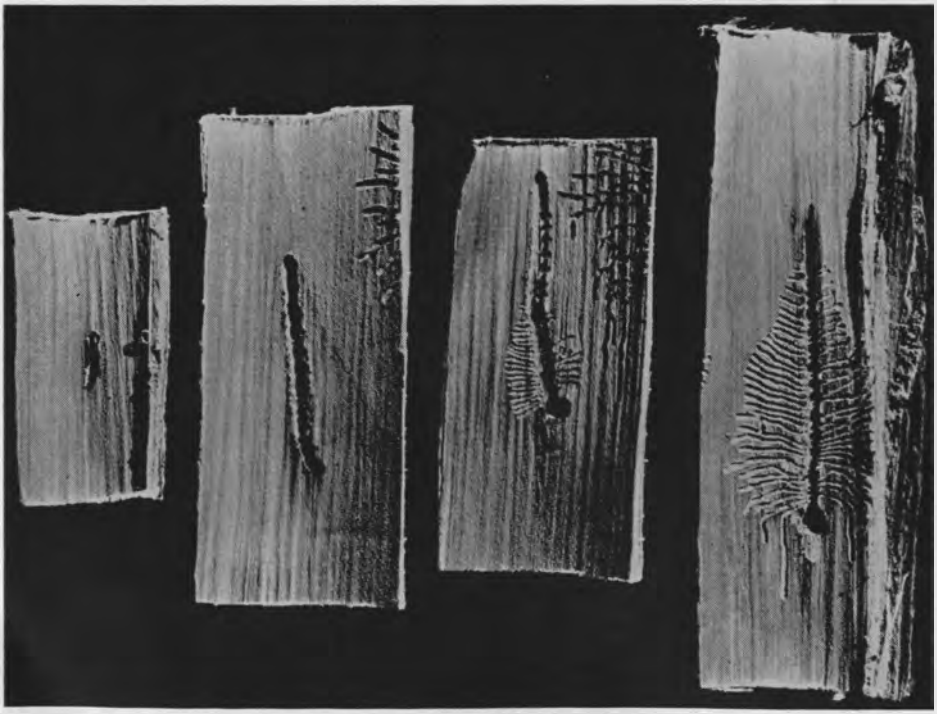

Fig. 8. Elm bark beetle tunnels on inner surface of bark and outer surface of wood. (a) (left) An adult female has tunneled through the bark and is constructing a maternal gallery parallel with the grain of the wood; (b) one week later the gallery is extended over an inch and eggs are laid in niches along each side of the maternal gallery; (c) even before the female completes ovipositing, eggs laid earlier hatch out young larvae that tunnel away at right angles; (d) a nearly completed bark beetle gallery presents its typical pattern.

carrying spores to healthy trees, the first step in preventing Dutch elm disease from spreading is to kill bark beetles. Overwintering larvae should be destroyed between October 1 and April 1 by burning or burying at least six inches deep all elm wood containing them.

Destroying infested elm wood during the summer eliminates many adult bark beetles that would produce the overwintering brood. During drouth years weakened trees attacked by many bark beetles for breeding would not survive. Where native elm bark beetles spread Dutch elm disease, larvae that would emerge as adults in October must be killed in August and September.

Too often sanitation programs fail because they ignore elm wood that has been cut and stacked or has died from causes other than Dutch elm disease. Such wood holds and produces spores that are spread by the new generation of beetles as they emerge. It can not be stressed too strongly that *any elm wood capable of breeding bark beetles can serve as a reservoir for Dutch elm disease infection.*

Furthermore, destroying breeding material means eliminating any possibility of bark beetles emerging from it. Storing elm for fire wood in a cellar or a shed will not prevent bark beetles from entering or emerging from it. Stored elm wood should have its bark stripped and burned. A less effective control is spraying the bark with a 2 percent DDT solution in fuel oil.

Spraying to Protect Valuable Shade Trees

Although bark beetles usually do not fly more than 1,000 feet from where they emerge to feeding places, they may fly considerably farther in search of breeding material. Healthy trees should be protected annually with a thorough *dormant application of DDT emulsion,* covering the tree from twigs to trunk base. This spray must be applied during the dormant season to insure a heavy deposit of DDT early in the spring when the bark beetles emerge. It may be applied any time during the winter and early spring when temperatures are above 32° F. The heaviest and most effective deposit will be present when the bark beetles attack if the spraying is done in late winter or early spring just before leaves break out. Sprays applied as early as November, however, have given good protection. Early application also reduces damage to birds and other wildlife.

DDT may be applied with a high-pressure, high-gallonage hydraulic sprayer (Fig. 9a) or with a mist blower (Fig. 9b). Either must have capacity to reach tree tops. To reach the top of a 50-foot elm tree with a high-pressure hydraulic sprayer it must deliver at least 20 gallons per minute with 600 pounds pressure. A mist blower must move at least 10,000 cubic feet of air per minute to reach 50 feet high.

DDT for bark beetle control is available commercially as 25 per cent and 32 per cent. The 2 per cent emulsion needed in a hydraulic sprayer is 8 gallons of 25 per cent concentrate added to 92 gallons of water or 7 gallons of 32 per cent concentrate added to 93 gallons of water. Trees are sprayed until the material starts to run off.

Mist blowers using air to carry the insecticide to trees apply a much

smaller amount of a more concentrated mixture. Most practical concentrate is 12 per cent DDT. At this concentration, one gallon of spray mixture contains one pound of DDT. Two to 2½ gallons of 12 per cent DDT emulsion satisfactorily covers a 50-foot elm tree. *Too much of this concentrated spray mixture will kill buds and small twigs.*

Repeated dormant sprayings with DDT may allow injurious populations of insects and mites to develop. Summer sprays of DDT are not recommended because bark beetle infection takes place primarily in the spring; but sprays to control mites, aphids and fungus diseases may be applied as needed.

DDT is poisonous to humans, warm blooded animals and birds. *Precautions on the label should be followed.* Aerial spraying will not deposit enough DDT to protect elms from bark beetles.

Preventing the Disease

Studies are being made to give trees immunity from Dutch elm disease and to eradicate the disease after it has appeared. More research is needed as both are promising, but not enough information is available at present to make recommendations.

General Tree Care

Fertilizing, irrigation, and pruning increase the health and vigor of elms. Elm roots are relatively shallow and compete directly with a lawn for water and nutrients. Trees require the same kinds of fertilizer as field crops. For most of Kansas, nitrogen and phosphorus are needed with potash added in southeastern Kansas. County agents have information on fertilizer recommended in your locality. The usual rate of fertilizing elms is ½ pound of actual nitrogen per inch of trunk diameter. A tree 10

Fig. 9. Spraying elm trees during the dormant season to protect them from bark beetle feeding in the spring; (a) (left) spraying with a high-pressure, high-gallonage hydraulic sprayer; (b) (right) spraying with a mist blower.

inches in diameter five feet above the ground requires 100 pounds of 5-10-5 or 50 pounds of 10-20-0 or 10-8-6. The amount of phosphorus and potash is not critical. The fertilizer should be applied in holes in the soil punched with a crowbar or drilled with an auger on either side of the drip line of the tree. The drip line is the line where the outermost leaves drip or the shadow line if the sun were overhead. About one pint of fertilizer is placed in each hole. Soluble fertilizer may be dissolved in water and forced into the soil with a water lance on a power sprayer.

Trees usually get enough water from a well watered lawn. In watering it is best to soak 12 to 18 inches deep. Shallow watering wastes water by increasing evaporation. The root spread of an elm usually exceeds its branch spread.

First object in pruning elms is to remove all dead, dying, and broken branches. Weak, shaded branches should be removed. Tops of trees should not be pruned severely because that decreases tree growth and starves roots and trunk as food is used to make new top growth, which weakens trees and makes them very susceptible to bark beetle damage. Thin wood pruning may be practiced in the top of the trees to permit light to reach the inner branches and the lawn below. All pruned wood should be burned immediately (see page 8).

Trees for Replacement

All American species of elms are susceptible to Dutch elm disease. This includes the American elm,[9] slippery elm,[10] rock elm,[11] winged elm,[12] September elm,[13] cedar elm.[14] European elms are susceptible, although one species [15] carries some resistance. Siberian elm [16] and Chinese elm [17] (the Asiatic species) are resistant. Water elm [18] and Zelkova are susceptible.

Hybrids of American and resistant European and Asiatic elms are now being studied to develop resistant strains. At present some resistant selections from the European species [15] are available. The commonest one is Christine Buisman which is now being grown in this country. It also resists phloem necrosis.

Shade trees to replace elms include these large trees for parks and large estates: pin oak, American planetree (Sycamore), bur oak, cottonless cottonwood, white oak, tuliptree, linden, Scotch pine, Austrian pine, baldcypress, pecan, black oak, sugar maple, green ash, and hackberry. Medium trees include: red, chinkapin and blackjack oaks, honeylocust, Norway maple, sugar hackberry, Japanese pagodatree, ginkgo, sweetgum, river birch, horsechestnut, black sugar maple, and London planetree.

Outlook for the Future

Frequently, after Dutch elm disease invades an area, plans are made to eliminate elms from future plantings. It is recognized that plans should be made to balance plantings with desirable species of trees. The

9. *Ulmus americana L.*

10. *U. fulva* Michx.
11. *U. thomasii* (*racemosa*) Sarg.
12. *U. alata* Michx.
13. *U. serotina* Sarg.
14. *U. crassifolia* Nutt.
15. *U. carpinifolia* Gleditsch.
16. *U. pumila* L.
17. *U. parvifolia* Jacq.
18. *Planera aquatica* Gnel.

danger that elms will disappear from our landscapes is more from not being planted than from all of them dying from Dutch elm disease.

In Connecticut the Dutch elm disease appeared in 1933, and spread slowly to every county in that state. By 1940 it was thought that the elm was doomed; today, however, the picture has changed. Recent research findings, including new chemicals for control, and resistant varieties, have resulted in an optimistic outlook. Healthy trees can be protected.

Summary

Dutch elm disease, found for the first time in Kansas in 1957, has spread through the eastern third of the state by 1960. Unless strenuous control programs are practiced, this rate of spread can be expected to continue and to intensify.

Dutch elm disease is caused by a fungus that prevents the flow of water from the roots to the leaves. Wilting and dying of trees from the tops downward follows.

The only way the fungus is carried from infected wood to healthy trees is by elm bark beetles. Beetles breed in infected dead wood and fly to healthy trees to feed, carrying spores of the fungus with them.

Dutch elm disease is prevented from spreading by controlling elm bark beetles. The principal step is to eliminate elm bark beetles by destroying dead and dying elm wood. Healthy elms may be further protected by applying a heavy dormant DDT spray. This spray gives maximum protection when applied in the spring just before the leaves burst from their buds. However, when necessary, a spray applied during November may give adequate protection.

The conscientious application of these control measures will not eradicate or eliminate the spread of Dutch elm disease, but it will keep the loss of elms to a reasonable level.

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Opportunities in Entomology

Entomology deals with the study of insects and their near relatives. In Kansas, as in most other state and countries, insects are the most important, destructive group of animals affecting man's health and welfare. There are more species on insects than all other species of animals combined. About 16,000 different species of insects occur in Kansas and 80,000 are known from the United States and Canada; and more than 700,000 are known in the world. This does not include the closely related spiders, mites, and ticks that also are included in entomological work.

About 4,500 professional entomologists are employed in the United States. Approximately 25 per cent work for the U. S. Department of Agriculture primarily doing research and animal and plant inspection; 10 per cent for other Federal agencies such as the U. S. Public Health Service, Army, Navy, and Forest Service; and about 15 per cent for State colleges, universities, and agricultural experiment stations, doing primarily teaching, research and extension work. Other employers are insecticide manufacturers, commercial pest control firms, privately endowed colleges and universities, museums, and private research foundations.

Entomologists may specialize in (1) "applied" entomology, which stresses insects' relation to plants and animals, including man; and/or (2) "basic" entomology, which involves fundamental studies of behavior, classification, physiology, toxicology, and various other studies in which insects are the animals under study.

Four hundred million dollars are spent annually to combat insect pests. Over 3 billion dollars in insect damage is reported annually in the United States alone. Insects are known to transmit many virus, bacteria, and fungus diseases of plants and animals, including many diseases of man.

There are also beneficial insects, such as honeybees, who pollinate plants as well as produce honey and beeswax. Other beneficial insects are those that kill harmful insects.

Students with a Bachelor's degree generally go into commercial pest control, sales and development work with insecticides, high school teaching, give technical assistance in research work, or do inspection work.

Students with M. S. and Ph. D. degrees become professional entomologists who supervise various entomological activities and teach or do research in colleges and universities.

There are about 100 full-time entomologists in Kansas who are engaged exclusively in studying insects and/or in insect control work. Several hundred others are engaged in work which is partly concerned with insects and their control.

Many youth who know that they cannot become farmers would like to hear of the many opportunities in entomology. You would do them, your profession, and your country a favor by making them aware of the opportunities—both in the United States and abroad.