DUTCH ELM DISEASE: AN OVERVIEW OF THE BIOLOGY AND MANAGEMENT REGIMENS

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Much of the information on the Dutch elm disease (DED) topic was generated by a large group of dedicated scientists, in several different agencies, primarily in the United States and Europe, over the last century. My work on the fungicidal management is but a modest contribution to the whole. It goes without saying that much more work needs to be done to open up new fields, and to hone established doctrines and mechanisms on the disease.

Here, I present an overview of biology and management regimens for DED:

A. Prophylaxis (prevention) is always preferable to therapy (treatment of established disease). This, of course, is true for managing many problems of life, not just DED!

1. Scouting and early detection are crucial when implementing any management procedure. The one-liner I offer for this is the old Revolutionary War dictum: *eternal vigilance is the price of freedom*. Scouting must be expedited by well-trained scouts and on a regular (and very short interval) basis during the growing season when symptoms occur. In my many years working with cities and communities, I have learned that most people are "tree huggers," and will join together as a community in protecting their trees—a shared wealth. Educational programs led by an enthusiastic and knowledgeable promoter can greatly effect recruitment of volunteer help. The Master Gardener program is a wonderful vehicle through which this might be done.

2. Sanitation is likewise a "first must" when disease is detected and confirmed. Sanitation, when effectively implemented, reduces the inoculum density (pathogenic fungal mass) and insect vector populations. Communities, cities, or home owners who delay implementing early sanitation procedures will suffer the loss of nearby susceptible, healthy elms. **Early sanitation**, that is, tree removal at the first sighting of symptoms is the ultimate, and really, only viable choice, whereas **delayed sanitation** is often worthless in efficacy. DED management in cities practicing either system provide historically sharp contrasts in saving or losing elms.

3. Root graft severance is strongly indicated when susceptible, contiguous elms are growing within root graft distance of each other (25 to 50 feet), as the pathogen can move through the grafts from a diseased to a healthy tree. Once infection has been contracted via the roots, death is assured, and chemotherapy is useless.

4. Vector management has a major impact on lowering transmission of the pathogen from infected to healthy trees. Management in times past has been effective via crown sprays of insecticides, but because of environmental contamination, fewer compounds are legal for use in recent years. Of course, sanitation (above) helps to reduce or eliminate breeding sites of the bark beetle vector.

5. Fungicide infusion/injection is a most effective tool in preventing disease, and we might term it as a type of "immunization." Many compounds in past times have been tested *in vitro* and *in vivo*, and a few of them employed, but currently, Alamo® (propiconazole; Syngenta AG, Basel, Switzerland) and Arbotect® (thiabendazole

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hypophosphite; Syngenta AG, Basel Switzerland) are now commonly marketed and used to preclude initial infection, and to treat established disease. Propiconazole is more "tree friendly" (that is, less toxic) than thiabendazole, but propiconazole does not move from treated xylem (wood) to newly synthesized wood following injection as thiabendazole does. Further, infusion of larger volumes of propiconazole has been found to provide better (more uniform) translocation than concentrated concentrations applied via micro-injectors, when both are used at the recommended dosage rate based on diameter at breast height (d.b.h.). Even though propiconazole residues cannot be detected more than a year or so after infusion, protection from disease continues to occur. The late Mark Stennes and I theorize that a phytoalexin-like response is induced by the fungicide, thus lending disease resistance years following fungicide application.

6. The use of disease-resistant and/or disease-tolerant elms in new (or replacement) landscape designs is crucial where elms are chosen for the treescape. Many sites in times past were planted with one susceptible taxon, for example, the fully susceptible American elm, as many like the symmetry and the Gothic arch effect when elms line both sides of a street. In many situations as this, DED can proceed down the line from one tree to the next via root grafts or by close proximity of the crowns where fungal-contaminated beetles can go down the line from tree to tree. The one-liner that fits this is "symmetry can lead to cemetery." Another might be "variety is the spice (or the preservation) of life." These, in short, address the problem of monoculture or the use of one taxon (cultivar, clone, hybrid, etc.) only. This is a "cat and mouse game," since the pathogen is constantly generating new pathogenic forms, and the fungus has the advantage over the host since the turnover in producing new pathogenic strains is much faster than can be done in the host.

7. Beetle traps using pheromones have been used effectively in some cases, but there are associated problems with it: fungal-contaminated beetles can be lured **into** a stand of healthy elms, rather than **away from** them. Wind direction is also often involved when traps are used.

8. Crown sprays were very effective when such products as DDT (dichlorodiphenyltrichloroethane) and methoxychlor (1,1,1-Trichloro-2,2-bis(4-methoxyphenyl)ethane) were used, but they have been banned because of environmental hazards. In some regions, permethrin-like compounds have been used successfully, but I am not sure if they are still being used, and if so how effective they are. The plant-derived insecticides are more acceptable environmentally as they have short residual activity, as opposed to DDT, methoxychlor, and other "old chemistries."

B. Therapy or the treatment of established disease (infection) has been used successfully in only a very few cases, and so for this reason pathologists always emphasize prevention over cure. To eliminate established infection, detection must be made very early at the earliest documentation, and infusion initiated immediately. This concept is tantamount to curing diseases (microbial infectious or some cancers) in humans and other animals. The major elusive problem is deciding if chemotherapy should or can be administered to the oftentimes extensive vascular infection that is nonvisible to the eye, as bark covers the xylem in which infection occurs. When infection reaches the tree base (shoot/root interface), a type of "metastatsis" occurs, and the fungal propagules are distributed in many directions into many vulnerable tissues. This writer came down with tick-mediated Lyme disease while volunteering in the Shenandoah National Park, and the immediate administration by his physician of doxycycline provided a complete cure.

I successfully cured the large American elm on the northeast lawn at Mt. Vernon (George Washington's home near Alexandria, VA). Detection in June 1979 was followed immediately with treatment using MBC (methyl-2-benzimidazole carbamate) phosphate as large volume infusions coupled with radical surgery. MBC is a highly anti-fungal derivative of benomyl fungicide. I also cured a large elm on the campus of Virginia Tech, one of the first cures attempted that I know of. Successful chemotherapy must be implemented at the very start of infection. In tracing the progress of vascular infection, it is well known that the vascular lesion is often present well beyond the visible foliar symptoms.

My colleague, the late Richard J. Campana, did some studies on the use of radical surgery alone in curing the tree of DED, which involves the immediate removal of symptomatic branches. Success was realized, but again knowing where and how to perform the surgery can be tricky as it is difficult, if not impossible, to determine where the infection exists in the symptomatic branch. There is a commonality of this procedure and in certain forms of human cancer, that is, early detection and immediate activity are keys to success.

Radical surgery and chemotherapy are handmaidens, and remarkable success has been realized when they are used wisely together.

Integrated pest/disease management can fit under either or both of the above categories, since it embraces both preventive and therapeutic activities. All weaponry and procedures should be employed to achieve maximum results in managing DED.