THE CHALLENGE OF WOOD DESTROYING INSECTS

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In 1984, R. V. Carr addressed the Canadian Wood Preservation Association on the subterranean termite problem in Toronto (Carr, 1987). In that address, he discussed his employment by the City of Toronto as a consulting entomologist, and the implementation by the city of the recommendations arising from that association. One of these recommendations was that the Department of Buildings and Inspections of the City of Toronto work with representatives of academia, industry, and the provincial government to develop a research program in urban entomology within the Faculty of Forestry at the University of Toronto. Although it has taken several years of organizational and lobbying efforts, this research program is now underway.

The primary goal of the urban entomology research project is the development of an integrated control program for the eastern subterranean termite, Reticulitermes flavipes (Kollar), in the urban environment. Obviously, such an ambitious goal necessitates basic, as well as applied, research efforts. To develop appropriate methods of control, one must first understand the behaviour and biology of the insect in the habitat of concern. Additionally, it is our intent that the research program expand with time to include other wood destroying insects, and the many other arthropods associated with man in the urban environment. In defining research priorities and directions, we wish to encourage input from all concerned parties, certainly including the membership of professional associations such as the CWPA which are concerned with the preservation of wood in service.

In this paper, I hope to provide an overview of wood destroying insects in North America, and a personal perspective on current research efforts with respect to their control. Although many of these insects may not be found in Ontario, or in other Canadian regions, the possibility exists of their introduction. Exterior environmental conditions may vary drastically from one area to another, but conditions within human habitations are frequently quite uniform. Once insects are introduced to a new geographic region, they can survive in our man-made environments, and frequently exhibit an unsuspected ability to adapt to different exterior conditions as well. Introduction may occur through commerce, or by casual movement of infested wooden objects, lumber, or even firewood. The eastern subterranean termite, for example, is thought to have been introduced to Toronto in infested material (Grace, 1987; Urquhart, 1953). Thus, an understanding of the wood destroying insects found in other regions of North America may help us evaluate their potential for introduction to Canada, and more rapidly and knowledgeably cope with such introductions when they occur.

Termites

Termites are certainly the most economically important wood boring insects in North America. The annual cost of termite control in the United States has been estimated at (US)$753,400,000 (Mauldin, 1986) to $1,020,000,000 (Edwards and Mill, 1986). Although only 69-80 of the more than 2,200 species of termites occurring worldwide infest buildings (Ebeling, 1975; Edwards and Mill, 1986), the costs of their control have been estimated at nearly (US)$2000 million (Edwards and Mill, 1986).

From an entomologist's point of view, termites are related to cockroaches and grouped into seven families: Mastotermitidae, Kalotermitidae (drywood termites), Termopsidae (rottenwood or dampwood termites), Hodotermitidae, Rhinotermitidae (subterranean termites), Serritermitidae, and Termitidae. The family Termopsidae is sometimes considered to be a subfamily (Termopsinae) within the family Hodotermitidae, particularly in American classifications. Only three of these seven families - Kalotermitidae, Termopsidae, and Rhinotermitidae - contain species of importance as pests in North America. In Canada, the eastern subterranean termite, R. flavipes (Rhinotermitidae), is found only in Ontario and two other species, Reticulitermes hesperus (Rhinotermitidae) and Zootermopsis angusticolis (and possibly Z. nevadensis) (Termopsidae) are present in British Columbia (Snyder, 1949).

Like ants and bees, termites are social insects. As such, they are characterized by three traits: (1) individuals of the same species cooperate in caring for the young; (2) there is a reproductive division of labour within the colony; and (3) at least two generations overlap in the nest, so that offspring assist their parents (Wilson, 1971). The specialized body forms, or "castes," found in termite colonies are a reflection of this division of labour.

The eastern subterranean termite in Ontario and a second subterranean termite, the Formosan subterranean termite (Coptotermes formosanus), in the southeastern United States provide examples of introduced pests thriving in their new environments. The Formosan subterranean termite was apparently introduced to North America through maritime commerce, and is now found as far north as Charleston, South Carolina, and as far west as Texas (Su and Scheffrahn, 1986). Unlike Reticulitermes species, C. formosanus readily nests above ground in buildings with no connection to the soil (Su and Scheffrahn, 1986). Coptotermes formosanus colonies are also larger and more mobile than those of Reticulitermes.

The author has observed C. formosanus chewing through plastic lids on containers in the laboratory.

In Ontario, R. flavipes was collected at Point Pelee in 1929 (Kirby, 1967), and is thought to have been introduced to the Toronto lakefront from the United States between 1935 and 1938 (Urquhart, 1953). Movement by man of infested materials has spread the infestation as far north as Kincardine. Currently, 28 municipalities in Ontario have reported subterranean termite activity (Cutten, 1987).

Wood Boring Beetles

Termites are not the only insects feeding on seasoned wood. Three families of beetles also commonly infest seasoned structural timbers and wooden objects: Lyctidae (true powderpost beetles), Bostrichidae (false powderpost beetles), and Anobiidae (deathwatch or furniture beetles). These are not social insects, but continued reinfestation of timbers literally reduces the wood to powder. The old house borer, Hylotrupes bajulus (family Cerambicidae - the longhorned beetles or roundheaded borers), is a serious pest in Europe which now occurs along the Atlantic coast of the United States (Robinson, 1986).

Beetles that normally bore into green wood may also cause problems when that wood is used in building construction. Although these insects will not reinfest the dry timber after emerging from it, their relatively long life cycles may allow the immature beetles to do substantial damage to the wood before emerging through finished surfaces or wall coverings as adults. Not infrequently, beetles in the family Cerambicidae, such as the 6 cm long Ergates spiculatus, cause this type of damage (Ebeling, 1975).

Occasionally, beetles infesting stored food products and not normally considered to be wood borers will cause serious damage. These occasional invaders of wood include larder and hide beetles (family Dermestidae) and spider beetles (family Ptinidae) (Ebeling, 1975; Grace, 1985b). It is unlikely that these beetles derive any nutrition from wood, and damage is usually reported only with heavy beetle infestations in granaries, grain elevators, mills, and packing plants. However, under some conditions damage can also occur in residential conditions, where it could be mistaken for that of the more common wood boring beetles and unnecessary or improper treatments applied (Grace, 1985a, 1985b).

Carpenter Ants and Bees

Neither carpenter ants (Hymenoptera: Formicidae, genus Camponotus) nor carpenter bees (Hymenoptera: Anthophoridae, genus Xylocopa) feed on wood. That is, they do not digest or derive nutrition from it. However, both excavate cavities in wood and enlarge existing cavities for nesting purposes.

Carpenter ants are most common in wooded, or recently wooded, areas. In Toronto, carpenter ant infestation is a serious problem in the northern portion of the city, but the damage is less significant and the costs of control are less than those associated with termite infestation (Jafri, 1983; Jafri, 1986).

Current Pest Control Technology

Current techniques for controlling wood destroying insects are thoroughly reviewed by Moore (1986). Although mechanical exclusion of insects from buildings is important (e.g., insuring that no timbers are in contact with the soil to exclude termites, and cutting back vegetation and sealing any cracks in the exterior walls to exclude ants), remedial control is most often accomplished with pesticides and fumigants. Although insects cannot survive on wood treated with preservatives, the thoroughness of the treatment, degree of penetration of the timber, and leaching of the preservative with time are important considerations. The degree of subterranean termite resistance imparted to the rest of the structure by the presence of a preserved wood (all-weather) foundation system is one area of current interest (Bryant, 1983). In this case, termite resistance would depend more upon insect repellency than upon the toxicity of the preservative.

In Ontario, subterranean termites are controlled by soil treatment with one of several cyclodiene chlorinated hydrocarbons (aldrin, chlordane, dieldrin) or an organophosphate (chlorpyrifos). A synthetic pyrethroid (permethrin) is available for use in the United States, and Canadian registration is anticipated. A carbamate insecticide (bendiocarb) may also be available for this use in the near future.

Wood boring beetles, and drywood termites, are usually controlled by fumigation with methyl bromide or sulfuryl floride (Vikane). Where carpenter ants and bees cannot be mechanically excluded from the structure, insecticide is applied to their nesting cavities.

However, many current methods of pest control are becoming less viable as a result of potential toxicological and environmental problems. In the United States, Massachussets and New York do not currently allow the use of cyclodienes for termite control (New York State Dept. of Environmental Conservation, 1986), and similar concerns have been raised by the Medical Officer of Health of the City of Toronto (Neighbourhoods Committee, 1986). The safety of fumigants has also generated public concern (Walter, 1985). Questioning of the toxicological and environmental safety of these materials has also brought about a sharp increase in the costs of liability insurance associated with their production and use. Thus, as the available materials are

restricted, the costs of pest control increase, and these costs are ultimately borne by the consumer.

Still, we cannot abandon wood as a building material, as was attempted by a couple in southern California who built a steel house to avoid termite infestation (Ryon, 1985). Even in a steel house, a house built entirely of pressure treated wood, or a concrete and steel apartment building, there will still be cellulose materials susceptible to insect attack. Stored boxes, books, cabinets, furniture, and wooden art objects are all susceptible to infestation by termites or beetles. The author has encountered spider beetles (family Ptinidae) mining a kitchen cutting board (Grace, 1985a, 1985b). Moreover, the many wood frame structures already in existence must be protected. The continuing need for safe, efficacious means of pest control necessitates the development of entirely new techniques for controlling these insects, rather than simply exchanging toxicants.

New Research Directions

Researchers are currently studying a number of promising alternatives or adjuncts to current methods for controlling wood boring insects. Among these are: biological control with insect pathogens; modification of the insects' behaviour with chemicals similar to those used by the insects to communicate and to locate food; interference with the hormones regulating growth and development; attraction to toxic baits; and the use of repellents and feeding deterrents. Many of the new approaches discussed here are also reviewed in somewhat greater detail in a new book on termite control (Edwards and Mill, 1986), received by the author after the original delivery of this paper.

A roundworm parasite of insects, Neoaplectana carpocapsae (family Steinernematidae), is currently produced and marketed for subterranean termite control. Certainly, this nematode is capable of killing termites (Georgis et al., 1982), but its efficacy under field conditions is still a matter of debate (Mix, 1986). In addition to environmental variables (temperature, humidity, soil conditions), a number of biological variables are also important in this complicated system: the nematode actually vectors a bacterium that produces a toxin, that in turn is the real cause of termite mortality. The interactions among these variables, and their optimal states, must be better understood to validate and further develop this biological control agent.

Other nematode species, other bacteria, and pathogenic fungi also offer promise for biological control. The fungus Metarhizium anisopliae, for example, has performed very well in laboratory tests against Reticulitermes species (Preston et al., 1982).

Chemicals affecting insect behaviour (semiochemicals) may also prove useful in termite control. Insects are dependant upon both "pheromones," intra-specific chemical messengers, and "allelochemicals," chemicals produced in their environment and used in orientation to food sources, etc. With blind insects such as subterranean termites, one would expect that such chemical compounds would be particularly important in communication and foraging.

Although the compounds responsible have not been identified, there is much experimental evidence that development of immature termites into specialized body forms (castes) is controlled at least in part by pheromones released by the other colony members (cf., Bordereau, 1985). Synthetic compounds known as "juvenile hormone analogues," which mimic naturally-occurring insect developmental hormones, interfere with normal caste proportions by promoting the development of excess soldiers within the termite colony. The mandibles (jaws) of the soldiers are enlarged and specialized for defense, prohibiting the soldiers from feeding themselves and making them dependent upon the worker caste for food collection. Thus, application of juvenile hormone analogues to the colony, generally in their food, has the effect of gradually starving the colony (Howard and Haverty, 1979). When incorporated into cellulose baits, these compounds offer promise for controlling Reticulitermes species. (Jones, 1984).

Termites also use pheromones to mark their foraging trails. Solvent extracts of the gland producing these pheromones readily elicit trail-following in Reticulitermes workers (Grace et al., 1988; Howard et al., 1976). The principal component of the trail pheromone of R. virginicus was identified as (Z,Z,E)3,6,8-dodecatrien-1-ol (Matsumura et al., 1968), and similar compounds may occur in other Reticulitermes species. Reticulitermes hesperus workers respond differently to different concentrations of trail pheromone, and are able to detect a gradient of pheromone on a trail (Grace et al., 1988). Compounds such as these may prove useful both in encouraging termite feeding on poisoned baits, and in actually directing termite foraging in a particular direction, such as away from structural timbers and towards a toxic bait.

Wood decayed by certain fungi also contains chemicals which induce trail-following in termites, or arrest them at baits. Decayed wood baits impregnated with a slow-acting toxicant (Esenther and Beal, 1979) or a juvenile hormone analog (Jones, 1984) have been demonstrated to suppress termite activity. In fact, the first field trials of this technique were performed in Ontario (Ostaff and Gray, 1975). The success of this technique depends upon (1) an appropriate arrestant or feeding stimulant, (2) a nonrepellent and slow-acting toxicant, and (3) proper placement of the baits to intercept foragers.

Termites appear to have feeding preferences (cf., Cooper and Grace, 1987), and compounds that influence termite survival and behaviour are found in undecayed wood from many tree species. Many chemical compounds are present in plants, and a variety of feeding (survival) and orientation assays must be performed with the wood from each tree species to identify all of the possible effects. These effects can include: feeding toxicity, contact toxicity, fumigant action, feeding deterrence, feeding stimulation, attraction, arrestment, repellency, or induction of trail-following behaviour. For example, a solvent extract of the Costa Rican tree Tabebuia ochracea both repels and poisons subterranean termites, an extract of Lysiloma seemanii is toxic but elicits no effect on orientation behaviour, and an extract of Pinus ponderosa is toxic and also has attractant and/or arrestant qualities (Grace et al., in preparation).

Certain plants also contain compounds which neither repel nor kill termites, but deter feeding by them. Grace et al. (1986) found that termites fed significantly less on a Japanese rice paper manufactured in a traditional manner with starch from the plant Lycoris radiata as a binder, than on a rice paper in which the plant starch was processed to a greater extent, or one manufactured with a synthetic binder. Although the differences in feeding were significant, the differences in termite mortality on the three rice papers were not, indicating feeding deterrence as the mode of action and the reason why the "traditional" rice paper is reputed to resist deterioration.

The Multi-Tactic Approach

There are a variety of promising techniques on the horizon for controlling termites and other wood boring insects. However, no single technique, or research direction, should be expected to solve all of our problems. Rather, different techniques and combinations of techniques will be appropriate under different circumstances. Certainly, wood treatment, perhaps even with behavioral chemicals, is compatible with this approach.

This multi-tactic approach to pest management, in which the goal is to combine techniques to exert greater and greater pressure on the insect population, is a departure from the panacea of pesticide treatment. As discussed by Frankie et al. (1986), such "thoughtful" approaches to pest management necessitate well-trained technical personnel, and public acceptance of the higher costs inevitably associated with more highly trained personnel and more specific treatment methods. However, well-publicized concerns for human health and the environment are forcing the issue. As old methods of pest control fall by the wayside, innovative research, accompanied by public and professional educational efforts, will help us meet the challenge presented by wood destroying insects.

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