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MODERATOR BORK: Our next speaker is from the Department of Entomology, Cornell University. Dr. John Weidhaas.

OBTAINING EFFECTIVE DILUTIONS OF INSECTICIDES WITHIN PROPAGATING STOCK

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This paper is essentially a review of research and a progress report on systemic insecticides as they may be used on woody ornamental plants. The wording in the title was chosen to emphasize the complex nature of systemics in relation to conventional contact insecticides which are simply diluted to the proper degree and applied externally on plants. My objective here is to discuss the nature of systemic insecticides as they are used on trees and shrubs, the knowledge gained to date, and the research needs of the future if systemics are to become useful tools of the plant propagator.

A systemic insecticide was defined by Bennett in 1949 as a substance which is absorbed and translocated to other parts of the plant rendering it insecticidal. Such a definition does not include chemicals which are simply absorbed into the plant, but not translocated. Some insecticide compounds are soluble in plant lipoids and, therefore, are absorbed into plant tissue (Gunther and Blinn, 1956).

The concept of systemic insecticides has been known for centuries. Yet practical use of this method is quite recent.

Selenium, used considerably in earlier greenhouse pest control, was the first systemic to be studied by entomologists (Hurd-Karrer and Poos, 1936). The first modern organic systemic was reported in 1947 by Schrader in England. In relation to all of our modern synthetic pesticides, systemics are not really so new since DDT became available commercially in 1945 only two years before the first systemic. Dieldrin and lindane were developed also in the late forties. As I shall attempt to point out later, it is much more difficult to achieve an effective dilution of an insecticide within a living, biologically complex plant than to simply apply a known dilution on its surface.

There are 4 major routes through which a plant system can be rendered insecticidal: the seeds, the roots, the leaves, and the bark. Seed treatment does not seem to be generally applicable to woody ornamentals. Treating leaves is not greatly different from conventional spraying. It does, however, provide a relatively simple method of application. Several approaches have been tried in treating the bark; by painting, by bark implant, and also by injection into the xylem. Root treatment is achieved by treating the soil and allowing root uptake as in the absorption of nutrients.

There are six major advantages in using a systemic type compound for insect control. First, it is possible to kill hidden insects such as aphids in curled leaves, or on roots; mites and insects in buds, galls, or bark; and eggs or very young insects in leaves. Second, the selectivity in killing plant feeders favors beneficial insects such as predators. Third, coverage of rapidly growing plant parts is possible in contrast to residual sprays which only cover existing shoots and leaves. Coverage is also possible on very dense and low growing plants which are hard to treat with spray equipment. An effective systemic would be taken up by the plant into all parts as they grow. Fourth, extended control should be provided, perhaps for an entire season, since roots continue to grow into systemic-treated soil. Fifth, the plants could be treated at a much more convenient time for the propagator and act as a fully effective preventive treatment. This would eliminate the need for emergency spraying or fumigating measures when other jobs must be attended to. Sixth, less total toxicant, less costly equipment, and less labor should be necessary for an insect control program.

Rather than discuss disadvantages as such, I should like to review some of the work which has been done to show the complexities and problems associated with the use of systemics.

First, what do we know about the relative toxicity to the operator? The values for LD-50 in Table I illustrate that most systemics are very highly toxic. The LD-50 is a standard reference which indicates the oral or dermal dosage in milligrams per kilogram of body weight which will cause 50% mortality in an exposed population of laboratory test animals. The conventional contact insecticides malathion, DDT, and lindane are included for comparison. With the most poisonous systemics, plants should not be handled within 5 days of treatment and full protective measures must be carried out without exception. Most growers are not sufficiently aware of the potential hazards of these chemicals.

Table I — Summary of Relative Toxicities for Systemic Insecticides Registered for Use on Ornamental Plants.

	LD-50		
	Oral	Dermal	Method of Application
demeton (Systox)	2-6	8-14	full coverage spray, soil drench
dimethoate (Cygon)	250	1000+	full coverage spray
Di-Syston	10-12	20	soil broadcast with granules
Meta-Systox-R	65-80	250	full coverage spray
phorate (Thimet)	1-2	2-6	soil drench
phosphamidon	16	267	full coverage spray
	Non-Systemic References		
malathion	1375	4000	full coverage spray
DDT	250	2510	full coverage spray
lindane	97	900	full coverage spray

The phytotoxicity of systemics was recognized early. The dosage necessary to kill insects feeding on the plant is very close to that which is toxic to plant cells, particularly the foliage. English and Hartstirn (1962) found that Bidrin injected into elm trees caused no injury at 0.5 and 1.0 ml. per inch of trunk diameter, slight injury at 2.0 ml., and severe damage resulting in defoliation from 4.0 and 8.0 ml. Norris in elm bark beetle control studies in Wisconsin has developed a very detailed crown class chart for elm trees to insure the exact dosage of Bidrin implanted in each tree. For systemics in general it is critical that exact dosages be applied. However, injury to plants has been least pronounced in soil treatments, and greatest with implants or injections.

In spite of about 15 years of investigation, systemics have had limited uses in insect control. Of some 26 systemic compounds studied, only 5 or 6 are available for commercial use. The registered uses are limited mostly to aphids, leafhoppers, leafminers, and mites. Table II summarizes the current uses suggested for growers in New York State.

Table II — Recommended Uses for Systemic Insecticides on Woody Plants in New York.

dimethoate (*Cygon*) 43% EC 1 pt./100 gals. water — SPRAY
birch leafminer, fletcher scale on taxus, fiorinia hemlock scale, honey locust mite, pine needle scale

Di-Syston 10% Gran. 1 - 2 lbs./Acre or 4 oz./inch trunk diam.—SOIL
aphids, birch leafminer, lacebugs, leafhoppers, mites

Meta-Systox-R 25% EC 1½ pts./100 gals. water — SPRAY
5% Gran. ½-5 lbs./inch trunk diam. — SOIL
aphids, birch leafminer, holly leafminer, leafhoppers, mites

phorate (*Thimet*) 10% Gran. 60 lbs./Acre or 3 oz. inch of trunk —SOIL
birch leafminer, holly leafminer, boxwood leafminer

phosphamidon 49% Spray Conc. ½-1 pt./100 gals. — SPRAY
Aphids, arborvitae leafminer, birch, elm, hawthorn, and oak leafminer, some leaf-feeding caterpillars

demeton (Systox replaced by Meta-Systox-R
Bidrin not registered for use in New York

Systemic chemicals in themselves are variable in mode of action (Ripper, 1952). Selenium is a stable material in that it remains in elemental form when translocated in the plant. Some systemics are endolytic; that is, gradually broken down to non-toxic forms when inside the plant. Older materials such as schradan and Pestox are in this category. Some systemics are endometatoxic, that is, metabolized into other or more toxic compounds once inside the plant. Bennett (1957) pointed out that the plant, instead of being a passive spray target, becomes an active physiological and biochemical participant in the application of the insecticide.

In a symposium in 1953, Wedding discussed the plant physiological aspects of using systemic insecticides. To be effective the insecticide must pass through the plant cuticle, cell wall, and plasma membrane. For non-polar organic compounds such as the systemics discussed here, absorption may be possible through the cuticle directly. It has been thought more commonly that penetration is generally through stomata. To be effective the compound must also penetrate cell walls and the plasma membrane which has the property of selective permeability. Once inside the cells, a systemic insecticide must be translocated throughout the plant. It is apparent that bark treatments would be most effective for materials moving in the phloem, whereas xylem implants or root uptake would result in movement through the xylem. Such movement is influenced by a number of factors such as temperature, carbohydrate storage, soil moisture, light intensity, and others. Wedding (1953), through the use of radioactive tracers, studied the movement of OMPA and Systox in beans and rooted lemon cuttings respectively. OMPA tended to accumulate more rapidly in young leaf and stem tissues. Systox applied in a band around the stem moved both up and down the stem from the point of application. The rate of movement varied from 2.5 cm. per hour down to 10 cm. upward. It was also noted that a diurnal effect occurred both in the direction and rate of movement. In studies with phosphamidon on hemlock, Randall and Jackson (1963) showed uptake from the foliage as well as cut stems, and movement both downward and upward in hemlock shoots. Some fumigating effect was also demonstrated. Work by Wallner and Weidhaas (St. John et al, 1964) with hemlock showed that dimethoate (Cygon) tended to move most rapidly into new shoots. Table III shows that the upper half of hemlock trees receiving soil treatments had a higher residue analysis of dimethoate than the lower. This was supported by scale control observations, since crawlers moving to new growth were killed as they fed on new needles (Wallner, 1962). Foliar sprays have been more effective with dimethoate as is apparent in Table III. Comparing that foliar residue analysis with that in Table IV it can be seen that heavy rain after treatment in 1963 resulted in less foliage residue, since no rain occurred for 2 or 3 weeks in the 1962 tests.

Table III — Residues in ppm of Dimethoate in Foliage of Hemlock*

1962 Treatment	Micrograms per gram of foliage 2 Weeks	5 Weeks	8 Weeks	11 Weeks
Foliar 1 pt./100	11.5	3.3	1.6	0.1
Drench 8 lb./Acre Upper ½	2.9	. .	. .	0.3
Drench 8 lb./Acre Lower ½	0.6	. .	. .	0.3
Drench 4 lb./Acre Upper ½	0.4	. .	. .	0.1
Drench 4 lb./Acre Lower ½	0.2	. .	. .	0.4
Untreated	.01	. .	. .	0.0

*St. John et al (1964)

Table IV — Residues in ppm of Dimethoate in Foliage of Hemlock.

1963 Treatment	Micrograms per gram of foliage 0 Weeks	2 Weeks	5 Weeks	8 Weeks
Foliar	24.0	4.0	0.8	0.0

The effect of rainfall calls attention to the importance of environmental factors on the effectiveness of systemic insecticides. The type of soil, soil moisture, availability of nutrients, soil cover, type of plant, and growing conditions must be taken into consideration if systemics are to be used successfully.

As a final point, it should be emphasized that many field experiments have been conducted with systemic insecticides for control of pests on ornamentals. To cite only a few, Schread (1956) in Connecticut has carried on numerous tests. Streu (1964) in New Jersey found that systemic controlled aphids on Easter lilies throughout the entire period of forcing. Donley

(1964) in Ohio obtained season-long control of mimosa webworm on honey locust with Di-Syston and phorate. Treece and Matthysse (1959) published the results of numerous field trials with systemics on nursery insects. In most of these field investigations results were not conclusive or clear-cut. Systemics did not seem to give the good results which had been anticipated. It now appears obvious that there are many physiological and biochemical complexities influencing systemic uptake, translocation, and detoxification. Detailed basic studies are necessary to determine the physical, chemical, and biological phenomena which occur in treated trees and shrubs. Undoubtedly, this will be achieved only through team effort by entomologists, plant physiologists, and biochemists. It is well recognized that plant physiologists themselves are still struggling to unravel the many theories of how water and nutrients are absorbed, translocated, and utilized by plants. All of these perplexing problems become the entomologist's problems when he tries to understand the mechanism of treating woody plants internally with complex organic chemicals.

In conclusion, systemic insecticides are known to be effective for certain limited uses in insect control on trees and shrubs. They need a great deal of investigation, particularly the basic approach to understanding the mechanism of absorption, translocation, mode of insecticidal action, and detoxification in the plant. Considerable research is being conducted in several countries on systemics, but we can anticipate that progress will be relatively slow. Increased cooperation will be essential between entomologists and plant physiologists.

In this paper I have attempted to highlight the principles and problems involved in systemic insecticides rather than simply review how they can be used. Hopefully this will provide you with a little better appreciaion of the research job which needs to be done and an understanding of the general nature of insect control with systemic insecticides.

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MODERATOR BORK: Now we had a little time for some questions.

DR. REISCH: I would like to ask Dr. Weidhaas if there is any oral toxicity involved, considering dilution in the foliage, from the use of systemic insecticides?

DR. WEIDHAAS: I am sure this question will get a lot more attention in the future. We do not have specific answers for that question, but as far as we know the normal exposure to the leaves of treated plants does not seem to be a problem. However, I think until we obtain more information, it would pay to avoid use of these materials in places where they will be exposed to the public.

DR. REISCH: The only reason that I ask this question is that the systemics are being used on home grounds and we receive calls at the University relating to children eating fruit or foliage, not specifically on treated plants but as a normal problem.

DR. WEIDHAAS: I feel that there is a safety factor here where the systemic materials are diluted. The eating is not habitual or a normal diet. It is an occassional situation and I don't think it is a great hazard.

MR. LESLIE HANCOCK: Is there any hope of systemic treatment of elms, particularly the large, old trees.

DR. WEIDHAAS: The state of Wisconsin has been doing the greatest amount of work on dutch elm disease control through bark beetle control. They have treated from 9 to 11 thousand trees in Milwaukee successfully. However, the chemical is not yet registered for use commercially. It is being used only on an experimental basis. It does not seem that it will be available next year, but perhaps the year afterwards.

VOICE: Dr. Weidhaas, I would like to ask a question about the treatment of plants with systox. Do you find in a group of plants that have been uniformly treated that a few plants still are infested?

DR. WEIDHAAS: I'm not sure I can give you an answer to that question. I think that when this does occur it may be due to differences in uptake by various parts of the plant. We find this in the case of elm trees which are forked very low and we inject the trees in the trunk. This material only went up one side of the tree and did not spread around. I don't know whether the same would apply to the roots when part of the roots are injured and therefore the concentration of the systemics may not be high enough in some parts of the plant and therefore the insects would be able to survive.

HANS HESS: Are there any results which indicate control of nematodes on the roots by the systemics?

DR. WEIDHAAS: There was a paper from New Jersey at the Eastern Branch meeting of the Entomological Society in October in Baltimore. He obtained excellent control of nematodes on azaleas but, I'll have to check my notes for the chemical.

ROLAND DEWILDE: I think Di-Syston was the one which was most effective.

PETER VERMEULEN: I would like to ask Al Fordham if the witches' broom plants retain their character or can we expect a reversion to the normal type?

[*Editor's note*: Al Fordham was not present when the question was asked.]

DICK VANDERBILT: Certain plants have a natural resistance to, say leaf minor. Is this resistance due to insecticides already present naturally or are they distasteful to the insects, or is this assumption true at all?

DR. WEIDHAAS: I think when we get done solving the nurseryman's immediate problems, we can take a look at some of these very interesting problems, but I don't have any information on this what so ever. I think this is an area that needs additional work.

DR. HESS: There are large varietal differences between plants and their susceptibility to insects. For example in water melons there is chemical which attracts cucumber beetles. You can cut open a melon which contains the attractant and in a few hours he melon is completely covered with beetles. A variety which does not contain the attractant has only a few bettles on it. The point is that varieties of the same species can contain different substances which may attract or be repulsive to insects.

DR. WEIDHAAS: Yes, there are as great number of very interesting examples where insects will avoid an individual plant and are attracted to another. For example, we know of two pink oaks in Buffalo standing side by side. One is completely covered with oak gall, the other without a single gall on it.

ROLAND DEWILDE: I would like to ask Dr. Weidhaas if the insects develop a resistance to systemic insecticides? We have run into this problem with a number of insecticides, particularly the phosphates. If you use them for 2 or 3 years, it doesn't kill the particular strain of mites any more.

DR. WEIDHAAS: No matter how chemicals are introduced into a plant the end result is a toxic effect upon the insect. So we can expect the similar problems of insect resistance. In the greenhouse a problem has developed with mite resistance to systemics.