SYSTEMIC INSECTICIDES

Entomological Aspects of Systemic Insecticides

LEE R. JEPPSON
University of California Citrus Experiment Station, Riverside, Calif.

Systemic insecticides may be expected to change the entomological approach to control problems, the pest species given emphasis, and the ultimate degree of control obtained. Certain pests now considered critical may be relegated to a more minor role. Dusts may be replaced by sprays adapted especially for applying systemic materials. As absorption, translocation, ultimate distribution, and degradation of these insecticides largely take place within the plant system, closer cooperation will be required between entomologists and research workers in other plant sciences.

SYSTEMICS SYMPOSIUM

SYSTEMIC INSECTICIDES—insecticides that are carried in the sap stream of plants and thus make such plants poisonous to insects—have certain advantages compared to conventional insecticides for control of some insect and mite pests. Their use may decrease the spray-coverage requirements and make possible the use of lighter application equipment, which would avoid excessive packing of fields and decrease the cost of application. Translocation of the toxicant in the sap stream may provide control of certain pests whose habitat prevents them from being reached by conventional treatments. The plant-feeding pests may be controlled by treating plant parts not inhabited by beneficial insects and mites, thereby obtaining selective insect control with a general toxicant. New plant growth that develops after treatment with the insecticide may be protected from insect attack.

One of the major problems in control of plant pests is that of distributing the toxic materials sufficiently to kill a high percentage of the injurious pest population. It is difficult to distribute residual insecticides so as to control the insects and mites inhabiting the undersides of leaves of plants growing close to the ground with dense foliage. Although materials that volatilize readily have given temporary reductions of active stages, the egg stages of the pests are not killed, as the residue life of these materials is relatively short.

In order to obtain complete spray coverage with residual sprays, especially to trees having as much foliage as the orange, it may be necessary to apply up to 3000 gallons of spray per acre. To operate economically under these conditions, equipment capable of holding 500 to 1000 gallons of dilute spray and weighing, when loaded, up to 12 tons is driven through alternate middles of citrus groves; this results in injurious packing of certain soils.

Pests that spend most or all of their life cycle in protected places have presented a particularly difficult problem in control by means of conventional insecticides. The citrus bud mite, *Aceria sheldoni* (Ewing), for example, develops under bud scales and fruit buttons that offer protection from conventional acaricide treatments.

Certain insects (notably aphis) and mites prefer the young developing leaves of the plant. In order to control these insects, especially those that migrate readily, frequent applications of conventional insecticides are required. The possibility of making toxic to insects the new growth developing after treatment appears to be a most promising advantage of the new translocated materials.

The application of nonselective insecticides to all the aerial parts of the plants reduces the populations of beneficial insects as well as of the pest. By using nonselective insecticides that are translocated in the sap stream, it may be possible to make applications to parts of plants not frequented by beneficial species and thus reduce injurious populations of plant-feeding pests without killing the natural enemies.

Problems of Evaluation

Information accumulated over many years relative to the use of residual-type insecticides—including knowledge of spreading and adhesive agents, equipment for distribution, and factors that influence weathering—may not be applicable to the systemic materials. The most effective use will require knowledge of factors influencing their absorption, translocation, and ultimate distribution of systemic materials in plants. The age of the plant, stage in growth cycle, weather factors, soil conditions, and physiological variations which influence absorption of materials from roots, stems, or leaves will need intensive study for complete evaluation of the effectiveness of a systemic material. Likewise, it is necessary to understand the nature of diluents, spreading or penetrating and stabilizing agents, and other additives, so that the rate or amount of insecticide absorbed and translocated by various plant parts may be increased without adversely influencing the physiology of the tree.

Variations in soil texture, moisture, and microbiology appear to complicate the factors that may influence the results of soil applications of systemic insecticides. Furthermore, the innumerable differences in soil conditions interrelated with variations in temperature, humidity, and sunlight multiply the complexity of factors influencing absorption and translocation.

As with contact insecticides, it will be necessary to ascertain the effects of the new systemic-insecticide applications on populations of beneficial insects. It cannot be merely assumed that applications to roots or stems of plants will not result in toxicity to predaceous or parasitic insects inhabiting the foliage or feeding on the pests under control.

Entomological Results with Systemic Insecticides

In 1949 Ripper, Greenslade, and Lickerish (*24*) found OMPA (octamethyl pyrophosphoramide) to be toxic as a systemic material to several species of aphis, mites, two species of leafhoppers, and a species of white fly and mealybug. Later Ripper, Greenslade, and Hartley (*23*) reported that on field crops about 5 to 6% of the applied spray was absorbed per hour, and uptake was best in leaves just fully opened, not so good in younger leaves, and still less in leathery, old leaves. Dry, hot weather was more favorable for absorption than humid conditions. Parts of the plant that were not present at the time of spraying, including seeds not then formed, become toxic through translocation from the sprayed, older parts.

Ivy *et al.* (*14*) found that spray applications of OMPA to cotton plants for control of the melon aphid, *Aphis ossypii* Glov., and a spider mite were toxic at 1 pound of toxicant per acre as a spray and at 4 to 8 pounds per acre as a soil treatment. At 25 pounds per acre soil applications were effective for 7.5 months. Cottonseed soaked for 2 hours with 2, 1, and 0.5% solutions of OMPA resulted in effective kill of the pests on developing seedlings for 35 days after treatment. Tsi (*27*) obtained mortality of aphis on young bean plants for 50 days, after seeds were soaked with OMPA for 24 hours at a concentration of 0.5%.

Dicker (*8*) obtained good control of aphis with OMPA when applications were made in May and June, but no systemic effect from October applications when the plants had almost ceased growth. Grob (*11*) found that the systemic action of Isolan (isopropyl methyl pyrazolyl dimethylcarbamate) depends much on humidity. At a humidity of 52 to 68%, aphids were killed from trunk applications to young apple trees in 72 hours, whereas it required 10 days at humidities of 90 to 95%.

Hanna *et al.* (*12*) reported that bisdimethylaminofluorophosphine oxide applied to the soil effectively controlled *Pseudococcus njalensis* and *P. citri* and did not prove detrimental to pollinating insects and certain parasites and predators.

Metcalf and March (*17*) studied the translocation, distribution, and degradation of OMPA in citrus from application to bark, roots, and foliage, in relation to its toxicity to insects and mites and its potential residues in the fruits. They showed by radioautographs that $OMP^{32}A$ was concentrated in the periphery of citrus leaves, but $H_3P^{32}O_4$ was most prevalent at the base of the midrib. The author has observed a wide variation in toxicity of lemon fruit to citrus red mite after treating the entire circumference of the tree trunk with a Systox concentrate or after making complete-coverage dilute spray applications.

In field studies Jeppson *et al.* (*15*) found that applications of OMPA and Systox, a mixture of *O*-[2-(ethylmercapto)ethyl]-*O,O*-diethyl thiophosphate and *s*-[2-(ethylmercapto)ethyl]-*O,O*-diethyl thiophosphate, to trunks of mature citrus trees resulted in toxicity to mites on leaves and fruit. The effects on mortalities of citrus red mite and citrus bud mite of Systox applications made from May to December to the foliage, trunk, or soil around mature lemon trees indicate that (1) soil applications are a very inefficient method of applying Systox to citrus trees as compared to spray or trunk treatments; (2) spray and trunk applications made from May to November are more effective than winter treatments; and (3) trunk applications are more effective against both species of mites than foliage sprays when applications are made from May to October, but are ineffective from November through the winter months. It thus appears that absorption and translocation of Systox are dependent on the physiological activity of the trees.

In preliminary laboratory studies by the author, stem applications of several of the more volatile systemic materials resulted in enough transpiration of toxic vapor through the leaves to be toxic to mites not in contact with the leaf surface, whereas transpiration vapors resulting from applications of OMPA and Systox were only slightly toxic to mites.

Limiting Factors

The grower, the ultimate user of insecticides, considers the ideal pesticide to be one that will control all of his pests for a season, without destroying the beneficial fauna, upsetting the normal development of his crop, or affecting the market value of the produce. The new systemic insecticides do not offer possibilities of meeting this ideal. To date, these materials appear to offer outstanding promise only in control of aphids, some plant-feeding mites, and limited number of other sucking insects.

The known systemics have not indicated outstanding promise in preliminary studies for control of chewing insects and a wide range of sucking insects, including scale insects, thrips, and most species of white flies, leafhoppers, and plant bugs. As with conventional insecticides, each toxicant may be restricted in effectiveness to a few pest species. Where several pests are present on a plant, additional treatments or combinations of toxicants will continue to be required for adequate plant protection. Until a wider variety of types of systemic pesticides has been developed, it will not be clear whether this specificity for certain insect and mite groups is inherent in all materials translocated in plants or whether the systemic materials developed thus far are not sufficiently toxic to some species.

Absorption and translocation of systemic materials appear to be at a minimum during cool, damp weather. Since many species of insects and some mites are favored by these conditions, the resulting control of normally susceptible species may not be satisfactory.

The use of systemics will be limited to nonfood crops until it can be established that either the pesticide itself or degradation products resulting from the detoxicating mechanisms within the plant are not chronically toxic to mammals. Ripper (*21*) indicates that there is no greater toxic risk from systemic insecticides than from surface insecticides of equal toxicity. The use of systemics on food crops may be delayed because new detoxicating mechanisms are involved. However, their use will ultimately be restricted no more than has been the case with surface insecticides.

Effect of Systemics on Pest Control

As with DDT, systemic insecticides will no doubt bring changes in the entomological approach to control problems, the pest species that will be given emphasis, and the degree of control obtained.

Certain pests now considered critical problems may be relegated to a more minor role in entomological consideration. Pests in this category obtain their food supply from the plant sap, but are not readily contacted by residual-type insecticides because of their habitat in the soil, under bud scales at leaf or flower axils, surrounded by curled leaves, or simply supplied protection by the contact of one leaf or fruit with another.

The use of bulky, high-volume sprayers or complicated air-blast mist applicators to distribute the contact insecticides to all aerial parts of the plants may become a less important phase of pest control. As dusts appear to be inefficient carriers of materials that are absorbed and translocated in plants, they may be replaced by sprays adapted especially for applying systemic materials.

The development of special types of application techniques for treating parts of plants is already in progress. Trunk and stem applications, special injection devices, capsules containing the toxicant properly situated for ready absorption, and varying methods of soil application have all been reported as promising methods of applying systemic materials under specialized conditions.

As many available insecticides effective against a specific pest have likewise been toxic to the parasites and predators, their numbers have been sufficiently reduced to be of little value in retarding the recurrence of injurious pest populations. Ripper *et al.* (*24*) pointed out the possibility of using nonselective insecticides with selective effect by applying them in such a way that they do not come in contact with the plant organs where beneficial insects occur. To realize the most value from these new opportunities of utilizing both pesticides and natural enemies, more extensive research will be necessary. More information is required in order to ascertain which beneficial species will be of most value in maintaining low population densities under conditions as modified by the treatment.

As the absorption, translocation, ultimate distribution, and degradation of the systemic insecticides largely take place within the plant system rather than on the surface, the entomologist will be more dependent on plant physiologists, biochemists, and other plant scientists for most effective use of systemic insecticides. The result should be closer coordination between entomologists and research workers in other plant sciences.

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SYSTEMIC INSECTICIDES

Plant Physiological Aspects of the Use of Systemic Insecticides

RANDOLPH T. WEDDING

Citrus Experiment Station, University of California, Riverside, Calif.

The development of effective methods for the use of systemic insecticides requires consideration of the physiology, biochemistry, and anatomy of the plants on which they are to be used. Permeability, translocation and accumulation, and activation and inactivation are problems in the field of plant physiology in which research work on systemics may be useful to entomologists. As examples of this type of work, investigations are reported in which radioactive tracer–labeled Systox and OMPA have been used. When Systox is applied to the stem or leaves of citrus plants it is translocated both up and down in the phloem at first, but gradually diffuses into the xylem and moves past girdles in the stem. The rate of movement in the phloem was determined to be from 2.5 to 10 cm. per hour.

SYSTEMICS SYMPOSIUM

THE DEVELOPMENT OF SYSTEMIC INSECTICIDES has brought into sharp focus the need for effective cooperation between entomologists and research workers in other fields of biological sciences. The active participation of the plant in the distribution and in some cases in the activity of these materials as insecticides makes it possible for a plant physiologist to contribute to both basic and applied research in the use of systemics.

Permeability of Plant to Insecticide

In the development of materials for use as systemic insecticides consideration should always be given to the physiology and biochemistry of the plants on which they will be used. The first point at which the plant must be taken into account in the selection and development of a systemic insecticide is the permeability of the plant to the material in question, or the rate at which it will pass into the plant tissue. As the insecticide must be present in or pass through living cells before the physical and chemical reactions which make it systemic can occur, the cuticle, the cell wall, and the plasma membrane must be penetrated.

The cuticle is usually highly lipoidal in nature, and thus nonpolar substances may penetrate more rapidly than ones that are strongly polar. However, the cuticle of most plants is interrupted by a variety of openings, such as lenticels, hydathodes, and stomata, as well as cracks and wounds, which may serve as