Honey Bees and Pesticides

Part IV

Guidelines for Future Honey Bee/Pesticide Research

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IN THE preceding parts of this series we have presented a chronology of bee/pesticide problems, a summary of relevant documented scientific facts, and a synopsis of serious misconceptions along with a perspective for the role of apiculture in a system of integrated crop management. In this, the last of the four-part series, we have drawn on the broad fields of the plant and animal sciences in an attempt to enumerate all of the research approaches we can think of that could contribute to an eventual reduction of bee losses. Research into some of these areas is already under way, either by ourselves or elsewhere. Other topics have not yet been studied relative to bees. Since no one individual or laboratory can possibly undertake all of the topics outlined, we hope that by presenting our ideas and questions, others may be stimulated to explore a subject of interest. Further benefit may be derived if others are able to relate their casual observations or insights to those presented herein and hence conduct more advanced research. Too, this discussion tends to point out the complex nature of bee/pesticide interactions.

It is our opinion, given the present state of bee/pesticide technology and a view of the future, that there is but one attitude to adopt regarding bees and pesticides: That is, since the use of pesticides on crops is likely to change little in the foreseeable future, we should attempt to minimize the amount of pesticide contacted by bees in the field and the amount that is carried back to the hive. In order to do this we must 1) become practicing partners in ongoing pest management programs, 2) test existing and new pesticide formulations and methods of application for reduced bee hazard, and 3) seek new knowledge regarding the interactions among pesticides, bees and the environment. It is these latter two points that we specifically address.

Research to date has clearly defined the problems encountered by beekeepers whose colonies are in areas where pesticides are used. It has identified relative toxicity to honey bees, based on the immediate acute mortality, of individual pesticides/formulations. Research has also provided some general methods for beekeepers, growers and applicators to use to reduce the hazards of these chemicals to bees. **Presently, our greatest limitation is that we cannot adequately predict the net effect of an insecticide application in any given circumstance. Moreover, normal biological and environmental variance greatly limits our ability to implement effective protective measures for bees.**

We must now delve much deeper into various aspects of fundamental bee biology and behavior if we are to further resolve the problem complex outlined in Parts I-III. Bold and innovative research approaches are needed. We must, for example, learn how to minimize bee exposure to field applied chemicals, determine the extent to which toxic effects are additive with repeated bee exposure and develop ways to rehabilitate a colony once it has been exposed. We must also determine the extent to which bees can biologically detoxify various chemicals, why some bees die from pesticides but perhaps more importantly why others do not die, what the principal sources of bee hazard are and how to diagnose sublethal or chronic effects of pesticides. In Parts I-III we have made a case for the significance of local/regional environmental effects, and certainly, the likelihood of these effects must always be kept uppermost in our minds.

There is a great need to identify the principal factor in bee kill situations and identify and rank all pertinent factors in decending order of importance. What, for example, is the leading cause of bee mortality from pesticides? Is it the chemical used? The formulation used? The level of exposure (dosage applied)? The frequency of exposure (including previous exposures)? The ratio of treated to untreated plants foraged by bees from a colony at a given time (plant competition)? Or is it the condition of the hive relative to its natural defenses against toxic chemicals? Answers here are especially needed to provide direction for research that is to follow.

Identification of Hazardous Pesticides/Crops

As we have already pointed out (Part I) it is the consensus of most who are involved in bee research that a majority of bee losses result from the application of a very few pesticides to a limited number of crops. If so, there is a need to ascertain which crops and chemicals are most frequently responsible for these losses. We are fortunate in that we have at least one fairly comprehensive source of bee loss data available from the Agriculture Stabilization and Conservation Service (ASCS) for 1967-1979. Therefore we strongly recommend that individual states compile from existing ASCS reports a list of crops and chemicals, ranked in order of the frequency with which they are used, and with which they harm bees. Initially, some research should be aimed at developing solutions for those crops and pesticides highest on the list.

Even though ASCS records are essentially our only comprehensive in-

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formation resource for bee mortality data, there is an inherent danger in using them to set research priorities because with such data we face the problem of trying to develop solutions based upon state boundaries which are biologically meaningless. So further interpretation will be required in most instances. Individuals in each state will have to identify the various biologically significant agricultural zones in their state and develop solutions for the specific problems within the confines of each ecological zone. In many cases these zones will extend into adjacent states and here cooperative effort should be strongly encouraged.

In a few states like California, where a great diversity of crops is grown, it may be more difficult to use ASCS Records to analyze bee losses. Nevertheless, we feel that if these states were to be divided into the appropriate ecological zones based on the nature of agricultural production and bioclimate, the ASCS data would be invaluable in precisely describing the circumstances under which most bee losses occurred.

In some states ASCS data has been compiled and is being used to identify the source(s) of the majority of problems. Yet elsewhere no such effort has been made. Unfortunately, unless action is taken soon these records may be lost or destroyed. Some states maintain records of the relative volume of pesticide sales via surveys. These records should also be analyzed and followed for current usage trends, although such trends may not always be tied directly to bee losses.

Pesticide Formulations

The most immediate benefits to be realized from bee/pesticide research will undoubtedly come from the study and development of insecticide formulations or methods of application of insecticides that are presently available, which reduce the likelihood that bees will contact and/or carry the poison back to the hive. We hold this view because: 1) the timing of spray applications, while highly beneficial in some areas, is impossible elsewhere; 2) persistence of a chemical varies with the region and its environment; 3) the source of poisoning does not always seem to be by direct contact with sprayed flowers; 4) although current guidelines recommend against spraying crops in bloom, other blooming plants in the vicinity of the treated area be-

Figure 1. The honey harvest. A) worker bee gathering nectar from a cranberry blossom. Pesticides are seldom used when cranberries are in bloom because growers are aware of the value of bees as pollinators. B & C) Blowing bees from a honey super. D) A novice beekeeper experiencing a harvest free from the effects of pesticides.

come coated with the insecticide resulting in bee loss; and 5) some major crops must be sprayed while in bloom to control particularly harmful insect pests.

Therefore, studies of formulations that stick or otherwise bind the chemicals to plant surfaces should be pursued most vigorously. To be sure, some such materials, such as Sevin XLR® and Penncap-M plus an experimental sticker, have already been developed and tested against bees. But, we must ask, are such sticker formulations equally effective everywhere? Are they as effective as other formulations now preferred to control pest insects? Should we look for those formulations best adapted to a particular environment? For example, will a water soluble sticker work equally well in dry climates and in humid climates where dew forms daily? Obviously, local testing of formulations must be carried out before such questions can be answered.

Environmental Factors

Earlier we emphasized the importance of understanding the impact of environment on the development of plants, the activities of bees and the effects of pesticides. The significance of this concept, underscored in Parts II and III, cannot be overemphasized, nor can we overemphasize the need to incorporate this concept into experimental designs. So while we can, with difficulty, perceive how weather, soil and climate may induce dramatic differences, we have too little data with which to work.

Much research remains to be done. It would seem that the easiest way to build a storehouse of knowledge would be to conduct similar experiments at several localities and compare the results. And indeed some of this has been undertaken. However, in this era of fiscal restraint, other approaches may be appropriate. The development of studies aimed at acquiring basic knowledge of the interactions of biological systems with environment requires considerable imagination and foresight.

There is a need for study of pesticide particle distribution on plant surfaces for the various pesticides. Do flowers normally have higher (or lower) concentrations of pesticide than leaves? Concurrent studies are needed to determine the amount of pesticide needed to kill target insects versus honey bees in the field. If such differences exist, can we use them in an effort to protect bees by regulating spray dosages?

Scattered throughout the literature on bees and pesticides there is frequent reference made to the fact that a given insecticide was toxic to bees at one temperature or humidity level (locality) but not at another. Such environmental effects are to be expected. Further study is needed to determine the mechanism(s) involved. For example, are these differences the result of relative volatility or persistence of the chemical on the plant or, could honey bee metabolic differences, perhaps in response to environmental change, play a role? How might these differences manifest themselves in the arid states of the southwest versus the cold climates of the north central states and Canada? Are there insecticides or families of insecticides that might be used without hazard to bees in one such area but not in the other?

An additional related topic that deserves mention here is the effect of naturally occurring electrostatic charges on the movement of pesticide particles in the environment. We know that small, dust-like particles are electrostatically attracted to bees, especially to antennal (and perhaps other) sensory receptors. Certainly, agriculture is beginning to use electrostatic sprayers for more efficient application of pesticides. Though unproven, it seems likely that pesticide dusts, microcapsules, or other particulate matter contaminated with pesticides would be differentially deposited on various plant surfaces and readily picked up by bees. Perhaps this notion merely speaks to the relative success in protecting bees already encountered by the incorporation of sticking agents in pesticide formulations. If we knew for sure, we might more rapidly develop these preventive measures against bee losses, particularly where peripheral sensory systems (like those on antennae and mouthparts) are affected. Here again, there will undoubtedly be effects of temperature and humidity on the electrostatic phenomenon.

Honey Bee/Plant Interactions

In our best judgment, many solutions to the bee/pesticide problem complex, particularly those outlined in the preceding section, will emerge from a fuller understanding of the differences in foraging behavior between honey bees and particular host plant species. Albeit simplistically, many have already taken this approach by strongly recommending that plants not be sprayed while in bloom. This recommendation is based on the assumption that the brief period of bloom is the only time of bee foraging on a crop (unless other plant species are blooming in the area or other unknown circumstances exist). Unfortunately, the broader more informed perspective is often ignored.

While we may know the approximate blooming dates of a particular plant species, the recommendation to avoid spraying during this period fails to recognize that we live in a world filled with biological variability. When there are acres and acres of a single plant species there exists tremendous intra-field variability in plant growth and development due to differences in soil composition, fertility, temperature and moisture as well as in ambient temperature, air movement and penetration of sunlight due to plant density. Hence, a flowering crop that is normally attractive to bees only in the morning may, in a large field, have individual plants with flowers open at many different times of the day. Bees will find these, so we must be concerned with levels of hazard from this standpoint.

For example, in Wisconsin sweet corn, we have recently shown that bees forage for dehiscing pollen from sunup to sundown for a period of 14-16 days. This is very different from the observations of other researchers, particularly in the western states, who report that bees there usually cease foraging on corn by midday. Their arid environments probably promote accelerated daily and seasonal periods of blooming activity. And indeed these scientists will be the first to point out that a dramatic change in one factor, such as weather, will significantly alter this period of bloom in their areas such that corn may dehisce pollen and bees may gather it all day long if the conditions are right. This comparison is merely one example of how extreme biological variability, that plant species exhibit in different circumstances, may alter the results of our efforts to protect bees. It is imperative that we take particular care in interpreting for our own purposes the results of studies done elsewhere.

As is often the case in other matters, we must think in terms of relative differences and not seek simple hard and fast rules. There are none! In each environment we must answer the question of what is normal flower development and/or bee foraging for a particular plant species as well as what the expected diversity might be. As with all such field research, studies must be repeated in several different areas of the United States if we are to understand the extent to which all variables impact on the results and if we are to optimize our efforts to prevent local bee losses. Only then can we superimpose meaningful national or regional pesticide/formulation use recommendations and restrictions.

Clearly our recent results show that in Wisconsin the recommendation to spray after 2:00 p.m. is wholly inappropriate because: 1) on fair days bees forage sweet corn from 8:00 a.m. to nearly 6:00 p.m. and 2) the late afternoon wind is normally higher than the maximum spray application limit of 5 mph. Moreover, the recommendation not to spray when significant numbers of bees are foraging in corn is equally nonsensical. Here, bees are foraging in corn during bloom for up to 14 days and this extended period is

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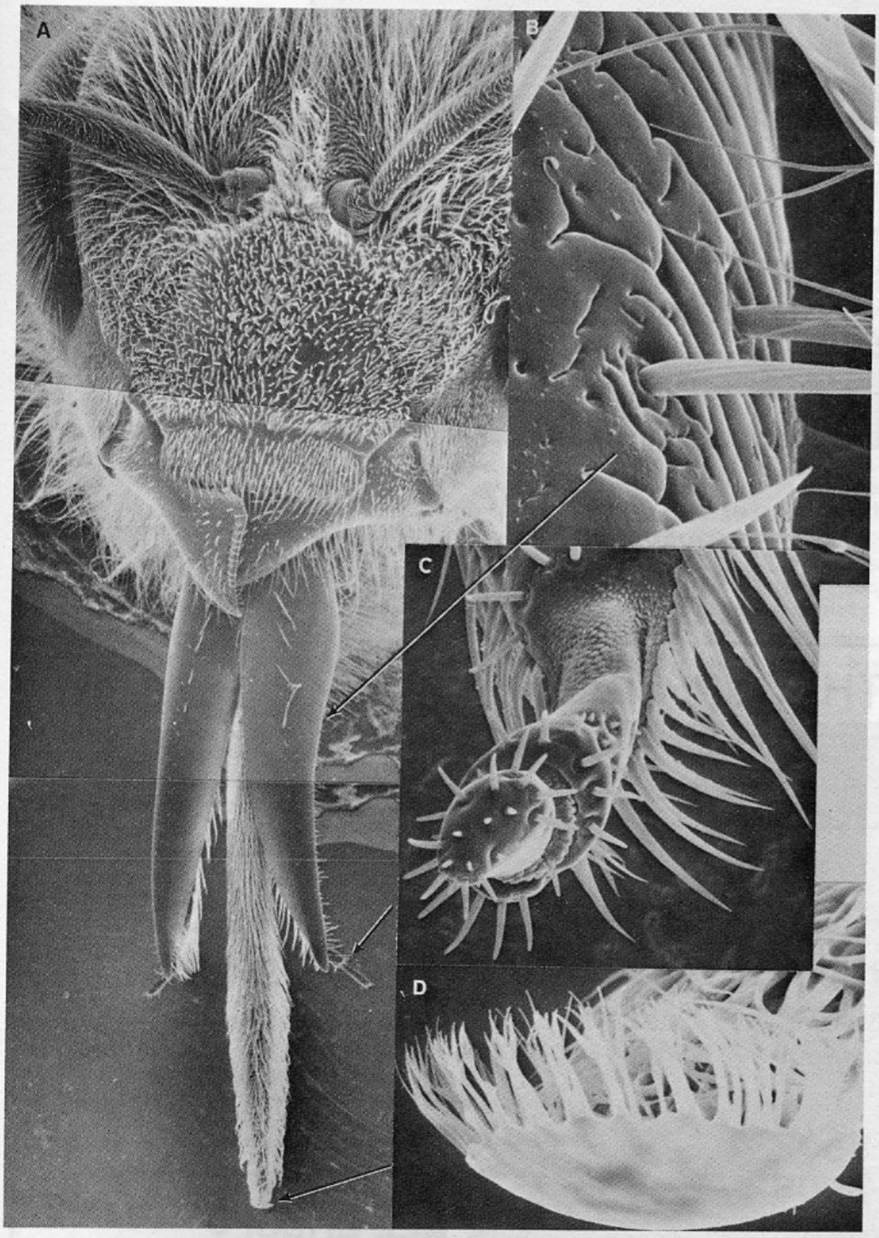

Figure 2. A) The face and mouth parts of a worker bee. B) Surface texture of the maxilla which surrounds the tongue. C) Touch and taste receptors on the labial palp. D) Flabellum on the tip of the tongue. Pesticide particles are easily acquired and transported on surfaces such as these. Sensory function may be lost with this contamination.

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too long for us to realistically expect the grower to wait to control pest insects. Obviously, more meaningful recommendations for Wisconsin are needed! What about other areas? Other crops?

For this and similar cases elsewhere we need much additional research.

Sources of Pesticide Contamination

There is little doubt that considerable honey bee mortality results from contact by the bee with a sprayed flower. There has been documentation of the effects of pesticide drift over apiaries and a minor amount of mortality may result from this. Also, some mortality undoubtedly results from the fumigant action of certain (mainly organophosphate) insecticides either in the field or in the colony. However, there are many other little known or seldom considered avenues by which bees may encounter lethal or sublethal doses of the poison. Dead bees, for example, build up at the hive entrance when colony mortality is high. Supposedly healthy bees then attempt to clear the entrance by carrying their dead out and away from the hive. So we must ask how much additional mortality accrues from this contact, and, how might we alleviate this problem? Some beekeepers attempt to keep their bottom boards clean after a bee kill.

Bees frequently gather and consume dew or use it to cool the hive. So one has to wonder about the effects on the colony of pesticide laden dew gathered from leaf surfaces. An orchard management program to eliminate blooming plants on the orchard floor might be helpful in some localities. But, if the rate of contaminated dew collection by bees is high in another area, this scheme might have little effect. Bees may also gather honeydew from aphids that feed on chemically treated crops like corn. What is the effect on bees here, particularly where high infestations exist, if the aphids are already poisoned or the honeydew is removed from an insecticide contaminated leaf surface?

With repeated frequent pesticide applications the toxins build up in the surface lipids and in the tissues of plants such that there is an additive effect with successive chemical treatments. When more than one toxin is present, synergistic effects become possible (i.e. two poisons acting in concert may be more toxic than one or the other alone). What then is the effect on bees? How does each of these rank in order of importance? Does this ranked order change from one region to another? Probably!

Are there not other such sources of contamination to be considered?

(To be concluded in February ABJ)