Honey Bees and Pesticides

Part III

Misconceptions and an Economic Analysis Viewpoint

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Part I of this series describes the honey bee/pesticide treadmill on which we find ourselves. In many areas of the United States we are no closer to "solutions" now than we were in the 1940's. Only the pesticides have changed. Part II of this series exposes our lack of understanding of the honey bee, pesticide, environmental interaction that has been responsible for our inability to escape this "treadmill." In Part III we address several misconceptions regarding bees and pesticides that must be dealt with in order for us to develop workable solutions to the honey bee/pesticide problem complex. We continue to examine reasons why pesticide use restrictions have failed to protect bees, and lastly we present the basis for the rationale behind an integrated crop management approach to reducing bee losses.

THERE are several widely held misconceptions that seem to hinder our ability to develop a solution to the bee/pesticide problem complex. Some of these are errors in interpretation of the facts and cause our efforts to be misdirected while others simply guide us up blind alleys. Three of these deserve our particular attention.

Repellents

First the terms attractant and repellent are misunderstood and frequently misused. "In the strictest sense the one thing that . . . attractants have not been shown to do is attract (i.e. to provide directional clues of use to an approaching insect orienting over some distance). The label . . . attractant masks a whole congregation of behaviors by the respondent such as orientation to wind and light."[20] Preferred terms, at least where bees and flowers are involved, would be "landmark" or "odor cue" and these act in concert with other cues associated with taste, touch and vision.

Similarly, so called repellents do not repel; rather they may deter certain types of activity or depress motor activity by repressing or blocking some part of the sensory system that controls nervous input to muscles. They commonly confuse bees for a short time by changing the odor associated with a reward or activity. However, bees may soon reorient to the new odor if a reward remains. In other cases they may not. Odor cues may "attract" bees or other insects at one concentration but "repel" them at another. Hence, while it is convenient to use the terms attractant and repellent because we seem to lack acceptable alternative terminology, we must not misinterpret their real meaning as we use them.

Honey bees will respond to any odor "pleasant or unpleasant" as opposed to none at all. So, to effectively use a material as a "bee repellent," we need additional information on its mode of action. Moreover, it must be tested in a variety of environments (the action of some compounds that block sensory receptors, i.e. permethrin, are temperature dependent[7] as is release of volatile components in insecticides and flower odors). Finally, we must ascertain the relative effectiveness of the chemical in situations where there is no forage alternative. The ultimate test is whether or not the chemical deters the foraging activities of sufficient numbers of bees for a long enough span of time so as to significantly reduce the hazard to the colony (the life of most volatiles is a matter of minutes or hours while that of pesticides is often a matter of

Figure 1. Insecticide applied to sweet corn.

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[3] Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products that may also be suitable.

days). Many of us have witnessed, situations wherein fewer bees foraged (were "repelled"), at least initially, but a lethal amount of pesticide was still brought back to the colony.

Perusal of the literature on bees and pesticides published over the last 40 years reveals that most (if not all) insecticides have "repelled" bees at one time or another; paris green, sulfur, DDT and other chlorinated insecticides, pyrethrin, and other botanical insecticides, pyrethroids (synthetic botanicals), Sevin®[3] and other carbamate insecticides and several of the organophosphate insecticides.[2,14,16,26,53] That none of these has consistently proven to be a reliable "bee repellent" in a variety of circumstances should be instructive. Recalling our earlier discussion of attractant and repellent concepts one can only conclude that any foreign substance applied to a plant (crop) is likely to alter the foraging cues of that plant resource for a period of time. Moreover, some insecticides are toxic to plants and therefore alter plant chemistry and may thus further affect the plant (flower) odor spectrum.[12]

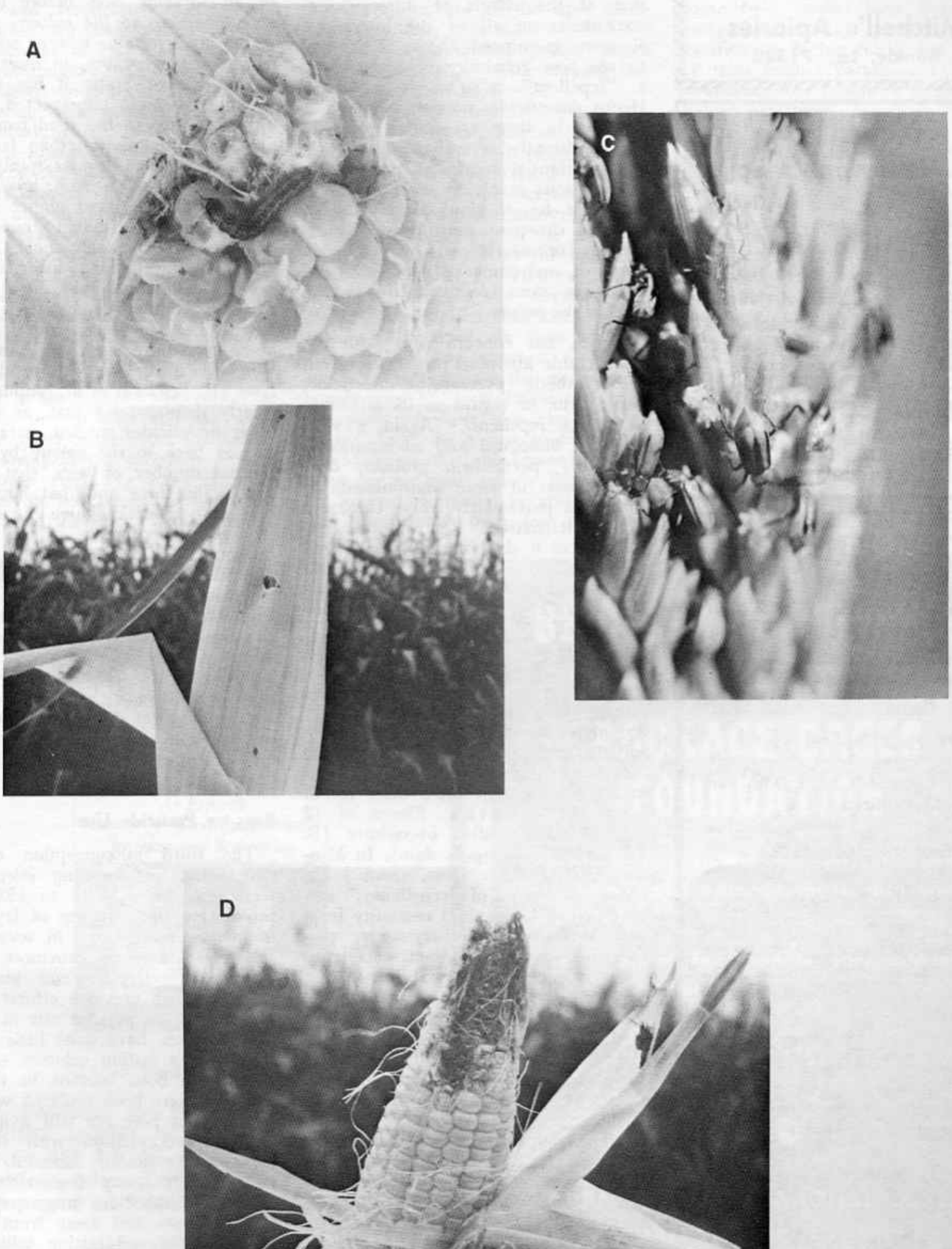

Figure 2. Why do we use insecticides? (A,B) European corn borer damage (C) Corn rootworm beetles (D) Corn ear worm damage. Would you buy this ear of corn?

Since foraging honey bees rely heavily on odor cues, it is not difficult to see how the spraying of a chemical over a field might temporarily confuse bees. This confusion, the result of the imposition of an altered or new odor, might be identified as "repellency" especially when identical plants are left untreated nearby and the bees are able to forage there unimpeded. Moreover, recalling our earlier discussion of the effects of differing environments on all of the interactive elements mentioned above, it is easy to see how reliability of response to a "repellent" might be affected. Hence, insecticides no doubt deter bee foraging in some areas, but probably not consistently or sufficiently to prevent substantial bee losses, particularly in situations involving extensive acreage. To be of significant value, a foraging deterrent must be totally effective (or nearly so) over a wide range of environmental conditions and have the same residual life in the field as the poison.

Hence, our concern rests with the considerable attention now being given the synthetic pyrethroid insecticide, permethrin, in regard to its attributes as a "bee repellent."[1] Again, given expected biological and environmental variability, permethrin probably does "repel" bees in some environments or situations, particularly where there are forage alternatives. Yet, in other circumstances it does not. In California bees avoid permethrin treated alfalfa fields for up to two weeks (E. Mussen, pers. comm.), but this may be the result of undesirable chemical changes in the plant affecting the production of floral nectar, pollen, odor and or seed.[12] In Wisconsin, we have found that while no repellency and no immediate acute bee mortality resulted from the use of permethrin, hazardous residues were carried back to the hive and persisted there for at least eight months: Eleven of 12 treated colonies died overwinter (B. Erickson et al., unpub. data). In Minnesota, B. Furgala (pers. comm.) did not see evidence of "repellency," and he observed high initial mortality from permethrin. In another study, permethrin odor or contact repellency was not evident except at the highest concentration tested (100,000 ppm). Yet, in related studies 70% of the bees died at concentration of 1 ppm.[28] Hence, beekeepers should not expect permethrin to be particularly less hazardous to bees than other insecticides: Neither should they expect it to be significantly more hazardous. In the Midwest at least, we cannot be lulled into complacency by believing pyrethroids are a salvation for the beekeeping industry. If we are, we may witness additional devastating winter losses in certain areas because these pyrethroids are highly toxic and persistent. Much additional study in diverse environments is needed before sweeping recommendations regarding pyrethroids as "bee repellents" are made.

Instant Bee Death From Parathion Insecticides

A second misconception we have encountered is that parathion and perhaps some other insecticides kill most or all foraging bees before they are able to return to the colony. We are unable to determine how or where this notion originated but, in most regions of the United States it has no basis in fact. As might be expected, slightly more bees die in the field from faster acting volatile poisons than from others that perform less as fumigants or kill more slowly. And, given their greater volatility, even higher immediate bee mortality may be experienced in some (particularly hot) climates (this volatility which leads to more rapid degradation may also be the reason why they appear less hazardous to bees in some studies). However, recent research in Texas and Wisconsin complete with residue analyses (B. Erickson et al., unpub. data) clearly demonstrates that, as with all other insecticides studied, parathion is carried back to the colony by a substantial number of bees, that it persists in the hive and that large numbers of bees at the hive die from it. In obvious acceptance of the misconception, pesticide applicators may be encouraged to mix parathion EC with other insecticides in the belief that it will kill foraging bees in the field and thus minimize or mask bee mortality. The folly of this concept has been shown by researchers[8,19,32] who have demonstrated the hazard to bees and to other insects of two insecticides mixed together may be greater than the sum of their effect if used separately.

Bans on Pesticide Use

The third misconception concerns the validity of banning selected insecticides. From 1892 to 1920, laws prohibiting the spraying of fruit trees in bloom were passed in seven states and two Canadian provinces. These proved ineffective and unenforceable.[25] Other previous efforts to ban insecticides, as pointed out in Part I of this series, have done little to contribute to a lasting solution — pesticides have been banned in the past and they have been replaced with new poisons, but bees are still dying. Excessive preoccupation with bans on pesticides is doubly harmful. It directs energy away from identifying those field situations most responsible for bee losses and away from achieving workable and lasting solutions to the bee/pesticide problem complex (see also Part I). Moreover, it removes from our grasp a potential intermediate remedy that someone in a particular environment/circumstance might find useful. Ideally, a lasting solution to the problem complex should significantly reduce the bee hazard from a wide range of poisons (including those yet to be developed) and across a variety of environments. To meet this objective, we in apiculture need to critically examine where we should apply our limited time, energy and resources. There is no justification for banning the use of any chemical unless it is shown to be extraordinarily hazardous to bees in nonbiased comparative regionalized field testing. And then the ban should be regional with additional concern given for the relative hazard of the material to be used in place of that which is banned. Recent attempts to ban microencapsulated insecticides present a classic study in the futility of banning insecticides.

The banning of microencapsulated insecticides (e.g. Penncap-M®, microencapsulated methyl parathion = methyl parathion ME) has become a popular pursuit. As in the past, there will probably be other pesticides so targeted in the future. Yet, sooner or later one has to stop and ask why? Like all other insecticides studied to date Penncap-M® is definitely hazardous to bees. And, like many other insecticides it is carried back to the hive where the active ingredient (methyl parathion) persists, particularly in the wax and pollen (see Part II), but not necessarily as intact pesticide filled capsules. It is argued that microcapsules, being similar in size to pollen grains, readily adhere to foraging bees and are incorporated into pollen loads. But so are pesticide particles from other formulations and particles of dust and debris that have been contaminated by pesticides. Moreover, because of the lipid affinities previously discussed,[10,11,15,17,18,22] pesticide contaminated pollen grains are "microcapsules" with varying levels of hazard to bees.

Significant bee losses have been attributed to Penncap-M® as noted by Barker et al.[5] in their review. However, two facts are rarely pointed out. First, unless the microcapsules were seen in the samples analyzed, there was no reliable method to positively identify Penncap-M® as the source of methyl parathion residues until a chemical method was developed in 1980.[13] More often than not no capsules were detected. In these instances Penncap-M® was assumed to be responsible rather than the much more widely used EC formulation of methyl parathion which is also carried back to the hive. In a few studies Penncap-M® was the only insecticide applied so we must assume that it was the source of methyl parathion. Second, there have been few published studies comparing the relative effects of encapsulated methyl parathion with other insecticides/formulations including methyl parathion EC when applied under identical conditions. Properly designed and controlled experiments such as this are the only way to develop meaningful answers.

There are now considerable conflicting data on Penncap-M® with regard to its relative hazard to bees. Some field studies have shown that encapsulated methyl parathion causes significantly higher initial bee mortality than methyl parathion EC.[3,4] Its persistence was presumed greater than methyl parathion applied as an emulsifiable concentrate in several uncontrolled studies.[5] However, comparative controlled studies in Oklahoma,[21] in Texas and again in Wisconsin (B. Erickson et al., unpub. data) have shown that less methyl parathion from the microencapsulated formulation gets back to the hive than from other more widely used pesticides/formulations (e.g. methyl parathion EC, Sevin® plus ethyl parathion and Furadan®) and that fewer bees die from it. Other recent studies have similarly shown the EC formulation of methyl parathion to be equally or more hazardous to bees than microencapsulation.[6,24] Workers in several states point out that while Penncap-M® is used in significant quantities comparatively few problems with bees result. Even so we must remain cognizant of the fact that Penncap-M®, like other insecticides, can and does kill bees.

Some would argue that microencapsulated insecticides are said to be notably bad because analyses have shown that they may persist in colonies for a year or more. But then one must ask, how many other pesticides/formulations have been evaluated with microencapsulated formulations in **comparative** tests? Certainly, as previously noted (Part II), independent testing has shown that several other pesticides persisted nearly as long before the respective studies were terminated and 2-4-5-T, pentachlorophenol and arsentical wood pre-

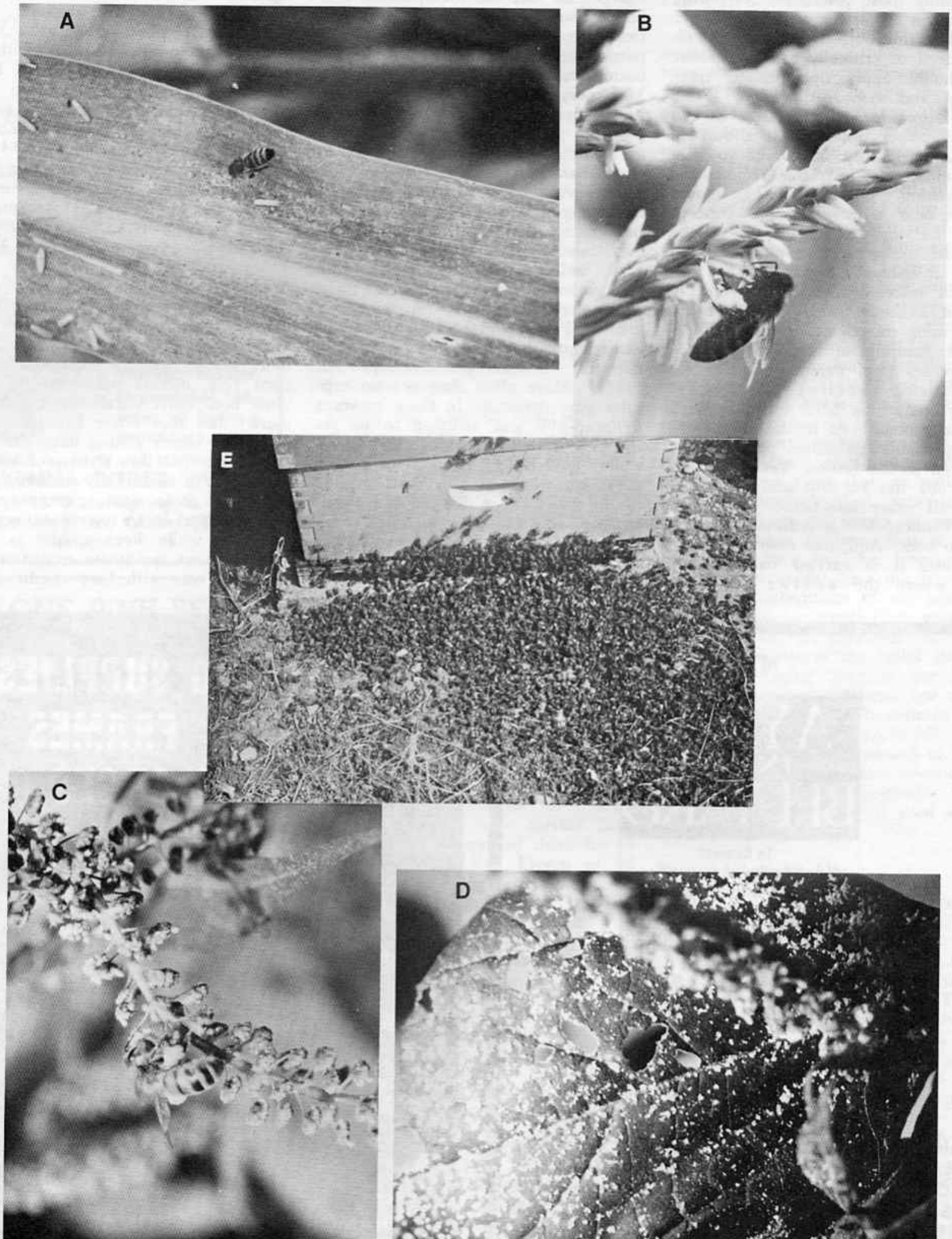

Figure 3. Honey bees are part of our agricultural system. (A) Honey bees gather sweet corn pollen from leaf surface (B) Honey bees forage sweet corn tassels (C) Ragweed growing around sweet corn fields offers increased insecticide exposure for honey bees (D) Ragweed pollen on leaf surface — an abundant supply of insecticide laden pollen occurs when effective weed control is not part of the crop management system (E) Dead bees are commonplace if integrated crop management is not practiced by ALL.

servatives persisted longer. The unusually high residues detected (about 5-40 ppm) in certain reported Penncap-M® analyses seem peculiar and are unexplained (see 5 and earlier discussion on residue levels). If one removes from consideration those studies wherein the use of Penncap-M® was not confirmd, then most, if not all remaining studies report similar (0-3 ppm) residue levels in bee hives and dead bees (comparable to those of other insecticides). Nationwide, encapsulated methyl parathion is responsible for comparatively few of our bee losses (see, for example, Part I, ASCS data). This may be due to its higher cost and limited effectiveness against certain target insects. Alternatively, it may be that less is used because of its notoriety within the beekeeping industry. Nevertheless, we cannot solve our major pesticide problems by banning chemicals or formulations that are only regionally hazardous.

One additional example illustrates the problems encountered by nationwide implementation of regionally developed pesticide use recommendations and restrictions. Studies in the more arid western states have shown methomyl (Lannate®, Nudrin®) to be safe for bees if applied in a fashion that would allow it to dry before bees come in contact with it. With this finding came the perception that methomyl is "safer for bees" everywhere. Hence, methomyl became widely recommended and used in the late 1970s. However, in 1978, in Wisconsin (see Part I, Table 5), its increased use clearly precipitated higher bee mortality. In a brief study to learn more about the effects of methomyl on bees in Wisconsin[10] we found its use associated with immediate adult bee mortality, persistence of residues in colonies for 8 months over winter, and winter loss of colonies; eight of eleven observed colonies died over winter. The winter colony losses were probably caused by the consumption of pesticide contaminated pollen stores and or stress induced by toxic residues carried over from the previous fall.* We presumed that the losses were due to the methomyl because we have seen similar colony decline with Sevin® (also a carbamate insecticide) but not with Penncap-M® (methyl parathion) contaminated hives. At the very least, these results show the need for further study in the Midwest and elsewhere.

So it is a perverse logic that allows us to universally and unequivocally condemn as too hazardous some pesticides/formulations after environmentally limited testing while similarly accepting other formulations as universally "safe and or repellent" after equally limited study. This shortsighted willingness to adopt regionalized results without question and apply them nation- or worldwide without further research has and will continue to slow real progress toward solutions to the bee/pesticide complex. The keyword here is *solutions* as it is unlikely that a single solution to the problem complex will be found.

Figure 4. Honey bees forage sunflower — Remember the honey bee pesticide complex exists for a diversity of crops and environments.

The Nitty-Gritty

Whether we like it or not, pesticides are an important part of world agriculture and they are here to stay for the foreseeable future. Our task is to learn to live with them and keep bees in their presence. Our success will be largely measured in economic terms.

There are three time frames to be considered in the economic analysis of a situation involving conflicting methods of agriculture such as the bee/pesticide complex. The first interval involves the beekeeper and only a single growing season at most or, perhaps, just a single spray episode. In this interval the beekeeper employs methods that are obviously stop-gap measures implemented as soon as possible to reduce the risk of or aid in the recovery from an application of insecticide to crops wherein bees are known to be foraging. These temporary measures are relatively easy to analyze in terms of dollars and cents; i.e. labor costs, equipment costs and replacement costs. When the different protective methods are tested under similar conditions, the relative benefit of each method becomes apparent. The final analysis will show which method provides the most protection in terms of colonies or bees saved per dollar invested. Only the beekeeper is involved at this level.

The second interval is intermediate in timing and involves beekeepers, growers and applicators. This situation can be difficult to analyze economically. First, several 'givens' must already exist. Beekeepers must already know the most efficient methods of protecting their bees on a short term basis (see above). Second, the grower or applicator must be practicing the most efficient methods of pest control feasible in a particular situation. This includes the initial choice of crops grown, the determination of the Economic Injury Level (EIL) of the chosen crops, the pesticides and formulations chosen and the methods, number and timing of applications. These practices may also involve several years as cropping practices, such as rotation, may increase or lessen the chance of pesticide exposure. The cost of protection per colony, the amount of income derived from each colony and the probability of losing a colony (the honey bee EIL) are the factors to be considered by the beekeeper in making an economic decision. The dollar and cents figure is less exact in this intermediate circumstance. It varies on a per colony basis because of external considerations such as inflation, recession, imports and exports, and the production potential of each colony as affected by weather or other environmental factors.

In the long term more than a monetary analysis is required since it also involves both ecological economics

* The spray regime in the studies involving overwintered colonies included 4 applications of methomyl and one application of Penncap-M®. Thus the late winter colony mortality may have been induced by methomyl or methyl parathion, or by some synergistic activity of the two. Colonies contaminated by Penncap-M® only normally survive the winter.

and socioeconomics. The end result of an intermediate decision will often dictate the long term decision. The outcomes of such a decision are complex and varied: 1) the complete demise of beekeeping (both hobby and commercial) from a particular area, 2) a significant reduction in the number of beekeepers (colonies) in an area, with emphasis on short term economics for those remaining, 3) no reduction of beekeepers (colonies), with emphasis on short or intermediate term economics, 4) a change in cropping patterns such that all or most crops grown are not attractive to bees or several highly attractive crops requiring pollination are grown in the same area, 5) a reduction in pest susceptible crops produced, with emphasis on intermediate economics, and possible confrontations with beekeepers, and 6) continued or increased production of crops requiring protection, with probable honey bee losses.

The ecological, social, and economic significance of the complete removal of any one type of agriculture from an area has been documented throughout history (the Irish potato failure, the Missouri cotton failure, the dust bowl in the western U.S.). The ramifications of the removal of pollinators from an area are too lengthy to discuss here. Certainly major considerations are the inevitable reduction of plant diversity and the probability of accelerated soil erosion. However, alternatives to the removal of bees must deal mith the economic decisions that must be made within the confines of conflicting methods of agriculture in any particular area. All of these situations must deal within the real world of dollars and cents, business survival and compromise. As Dr. Eva Crane, Director of the International Bee Research Association, has pointed out "the best that beekeepers can hope for, in the light of the great need to kill pest insects, is an "acceptable level of mortality among their bees."[9]

Where Do We Go Next?

Over the years, important and extensive studies by L. Atkins and others have been conducted to compare the relative toxicity of various pesticides to bees. However, these alone do not produce all of the data needed to solve the complex of problems. These studies are not sufficient to reveal relative toxicity under different field conditions[23] because of the aforementioned variability among chemicals and their interactions with plants, bees, and environments.

From past experience, recent studies, the constant evolution of new insecticides and formulations, continued bee losses, and the resultant hardships imposed on crop growers or applicators, it is obvious that innovative new approaches, guidelines and proposed solutions to the bee/pesticide problem complex are called for. Quite probably, an increasing burden for resolving the problem will fall on the beekeeper who should and will continue to be called upon to function as a full partner in area wide integrated crop management programs. Many beekeepers have already significantly reduced their individual bee losses through close cooperation with growers or applicators.

Scientists are similarly compelled to develop new research approaches and solutions to this age old problem complex. In the fourth and final paper of this series we will attempt to identify a number of avenues of study that should be undertaken. These are needed to compile basic knowledge upon which we can eventually base new solutions tailored to particular sets of environmental circumstances, families of insecticides or insecticide formulations.

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