Honey Bees and Pesticides

Part I of a 4-Part Series

Plain Talk About the Past and Present

by ERIC H. ERICKSON, JR.[1] and BARBARA J. ERICKSON[2]

Ever since paris green, the first insecticide, was used to control insects over a hundred years ago, beekeepers have experienced losses from pesticides. Such losses now occur worldwide.[1] Repeated efforts to protect bees from pesticides have been made but the problem persists. This is the first of a 4-part series which attempts to address this critical issue in some depth. Our objective in this first part is to present an historical perspective and to critically analyze the magnitude and extent of these losses to bring a quantitative perspective to the problem.

THE following report typifies the problems that beekeepers experience from pesticide use:

From one to four applications of five different insecticides were applied to 4,810 acres of cotton in the Salt and Gila Valleys of Arizona. There were 2,530 colonies of honey bees in the treated area. Of these, 500 were killed outright or so seriously affected that "they have little chance of survival." This acute damage was inflicted by only two of the five insecticides used, although many other colonies were weakened by the other chemicals and may have experienced a gradual decline "as described in the beekeepers' reports."

The sales agent for the most damaging of the five insecticides used indicated that if it proved to be particularly hazardous to bees "he would stop handling it." The pilots for the two companies responsible for all of the crop dusting in Arizona are "anxious to learn as much as possible about how to avoid harming bees. The *(sic)* are well enough acquainted with agricultural crops to know the value of bees for pollination, and are anxious to see the poison question solved. That one beekeeper has threatened to sue them this year and another is reported to be suing a farmer whose cotton they dusted makes them still more anxious to see the question solved. We have spent considerable time together in discussing different angles of the problem and they have often offered excellent suggestions. On several occasions they have made observations for us as to bees, drift, vegetation, and atmospheric conditions."

Differences in performance among pilots was noted with some showing care by flying closer to the crop than others. Accidental or careless application of the insecticides to nontarget areas including apiaries was observed.

"Bees were collected in a cotton field with . . . [insecticide] on them five days after the field was dusted" and "at hive entrances . . ." with the insecticide "in their loads of pollen." Insecticide drift was evident with insecticide "particles [found] on the tops of hives" and on plant surfaces up to "1½ miles across the desert from the dusted field." In one instance a drifting cloud of insecticide "moved directly over an apiary."

One component of the less toxic insecticides has been reported to repel bees "in many references." However, no such repellency was noted. "On the contrary some bees can practically always be found in dusted cotton even immediately after the plane flies over the plants."

"Our recommendations to the beekeepers remain. Move the colonies before dusting begins, if you cannot do that, screen the top and entrance for a day or so until you can move them. Cooperate with the farmer by letting him know where your bees are and how he can contact you before he applies the dust."

Does this story sound familiar? What you may find startling is that **little has changed since 1944** when these initial findings and recommendations from southwestern Arizona were presented by Mr. E. E. McGregor, Apiculturalist, USDA-Pacific States Bee Culture Laboratory, Davis, CA[9,10] who was transferred to Arizona to study the problem of bee losses after 7,231 colonies were lost there in 1942.

The foregoing sounds like a report from this past season complete with reference to misapplication, insecticide drift and overspray, lawsuits, reports of insecticide repellency and plans for the banning of insecticides. In 1943, in Davis, California, a pilot's license had been revoked following application of calcium arsenate to tomatoes.[8] Here and elsewhere, recommendations for late evening or early morning applications of insecticides were occasionally ignored by growers and applicators when it was necessary to meet pest insect control objectives. Today, only the insecticides and formulations used are different. Even the recommendations for protecting bees in many states have not changed appreciably in the nearly 40 years since McGregor recommended that the colonies be moved

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or the bees be confined during and after application. His perceptive suggestion that beekeepers develop close working relationships with neighboring growers and pesticide applicators is still our most viable remedy. We now consider his suggestions an essential part of integrated crop (pest) management programs.

The five insecticides used in 1944 were: sulfur plus paris green (cupric acetoarsenite); sulfur plus Quik-kill 15% (a mixture of tricalcium arsenate and calcium arsenite); sulfur plus Quik-kill 30%; basic copper arsenate; and DDT (dichlorodiphenyltrichloroethane) The calcium arsenate in the Quik-kill dusts was deemed the most hazardous to bees. The presumed repellent material was ordinary sulfur which, depending upon formulation, comprised up to 90% of the mixture.[9,10]

Mr. McGregor summarized his work, begun in May of 1944, as follows:

"Apparently many things enter into the seriousness of poisoning of a colony. Not only the kind of dust used, the way it is applied, the plants dusted, or the weather, but more important we believe is pollen and nectar secretion. If cotton is dusted on one side of an apiary when a field of alfalfa in the opposite direction is yielding nectar heavily, the apiary might escape serious injury. Yet the same field may be dusted in the same manner at another time and the apiary could be destroyed.

"Our observations have shown that the arsenic in the dust does drift in considerable quantities within the first mile and smaller amounts as far as two miles. These observations were by arsenical analyses, particle observation, and bee reactions. Not only cotton but other plants as well are contaminated by the poison. Identification of poisoned pollens trapped at the hive entrances and taken from hives has also shown that poison is obtained 'away from the poisoned field.'

"Farmers, cropdusters, and insecticide men are interested in seeing the bee problem solved, and have been very cooperative in allowing us to make observations and are willing to alter their materials or methods of application to save the bees but do not want to be restrained from applications. The burden of developing a method or recommendation to save the bees is placed entirely on the shoulders of the bee industry.

"The problem has been attacked with the belief that a solution without legal action is possible. Many more samples will have to be collected and analyzed, many more observations made, and many controlled laboratory experiments conducted before the solution is obtained."

A ban on the sale of Quik-kill dust in Arizona was proposed beginning in 1945.[10] However, that year more than 6,800 colonies were reported lost due to use of this insecticide as well as others on cotton and vegetables.[11]

By December, 1946, Mr. McGregor had been transferred from Yuma, AZ to Madison, WI, because arsenical insecticides were identified as the definitive bee hazard and the problem was apparently considered resolved with the introduction of DDT. "Damage in Arizona from insecticides in 1946 was at a new low because of the virtual ban on the use of arsenicals."[12]

Looking back, we can only conclude that the restraint exercised in the use of arsenicals, "because of their toxicity to bees," had little to do with the conversion to DDT. We can find no record of a legal ban. Rather, the motivation was a simple matter of economics and the coincidental post World War II emergence of a new class of insecticides, the chlorinated hydrocarbons including DDT. The change was from poisons (the arsenicals) that cause immediate, acute toxicity, and require a complex detoxification system, to poisons (the chlorinated hydrocarbons) that were far less expensive to use. These latter poisons are now banned, because it was found that they are stored in living tissue (including fat) and, hence, have more subtle toxic effects. In 1946 studies began to show that DDT and many of the other chlorinated hydrocarbon insecticides were highly hazardous to bees.[3,4,7] This cycle has been repeated numerous times since — as each new insecticide or class of insecticide is developed, research and experience soon reveal its toxicity to bees.

Several very important questions must now be asked. Should we continue to encourage history to repeat itself with new insecticides? Can we successfully fight the problem with bans, lawsuits, and "repellents"? Have we even adequately defined the problem? Does our present course of action differ enough from that of the past such that we can now expect solutions to the problems of bee losses from pesticides? Should we now establish a new course(s) of action?

The Complex Problem — A Perspective

Bee losses following the use of paris green in blooming orchards were first observed in the early 1870's.[7] "Research to resolve the problem of bee losses due to pesticides has been underway since 1881 when damage to bees by lead arsenate was first reported. A century later, there still is no solution to this problem . . ."[13]

even though a barrage of lawsuits, efforts to ban or restrict the use of certain insecticides, and research projects has ensued. If we take the narrow view and consider only bee mortality we would seem to face only a single problem. However, any crop that bees visit and on which pesticides are used is a potential bee hazard. If we interject the vagaries of environment, blooming weeds, differing insecticidal modes of action as well as differences in bee behavior and plant development due to environment, we quickly come to the conclusion that we are dealing with a complex of problems. Perhaps this is why simplistic solutions proposed in the past have been inadequate.

In 1980 the total acreage of crops harvested in the U.S. was 353 million + 59.6 million acres of hay crops. Of this acreage 1.4 million acres was for seed crops, 3.0 million for vegetable crops, 3.6 million for fruits and nuts, 13.2 million for cotton, 67.9 million for soybeans, and 70 million for field corn (USDA Agric. Stat., 1981). The Economic Research Service (ERS) of the USDA periodically surveys pesticide usage in the U.S. The latest published survey, taken in 1976 indicated that herbicides were applied to 56% of the crop acreage, with cotton and corn acreage having 84 and 90% treated. Insecticides were used on 18% of the crop acreage, fungicides 2% and pesticides 2%. In 1976, 38% of the corn acreage and 60% of the cotton acreage was treated with insecticides (see discussion of systemic insecticides below). Although no specific information was available for fruits and nuts, potatoes and other vegetables for 1976, in 1971, 90, 84, and 58% of the acreage respectively was treated with insecticides for these crops.[2,5]

Fungicides, nematicides and plant growth regulators are of minor importance in terms of overall destructiveness to honey bees. Insecticides are the most acutely toxic, causing a direct and immediate impact on honey bees as well as long term effects. Although occasionally toxic, herbicides usually cause a more subtle effect by reducing the availability of nectar producing ground cover for honey bees (see Part II). This may result in a decline in the overall condition and productivity of the colonies.

In the 1976 ERS survey, the major insecticides used on crop acreages were in order of acres treated: methyl parathion, parathion (= ethyl parathion), carbofuran, carbaryl, disulfoton, phorate, dyfonate and toxaphene. These insecticides accounted for over 71% of the total acres treated. Carbofuran, disulfoton, phorate, and dyfonate are primarily used as soil insecticides, but this use may have adverse impact on honey bees when they are used as systemic insecticides or applied during bloom (see Part II).

A preliminary evaluation of the 1982 ERS survey indicated that the total poundage of insecticides used on crops dropped from 130 million in 1976 to 54 million in 1982. This decrease was caused by the introduction of synthetic pyrethroids such as permethrin and fenvalerate in 1978. These materials are used at about 10 fold less lbs. per acre than other insecticides. The full extent of their toxicity to honey bees and potential for damage has not been fully evaluated, but preliminary studies indicate that they are acutely toxic to honey bees.

Quantitative Analysis of Honey Bee-Pesticide Losses

In the United States, the combined annual cost (loss of bees, honey production and pollination) of honey bee poisoning is approximately $135 million.[1] Using the parameters tabulated in Table 1, analyses of data from the Agricultural Stabilization and Conservation Service's Bee Indemnity Payment Program (ASCS-BIPP) reveal that monetary losses to beekeepers for the period 1967-1978 averaged 3.8 percent of the total value of the colonies kept in the United States (Table 2, column D). If these losses are instead calculated on the basis of beeswax and honey produced (see Tables 1, 3), the average is 6.2 percent (Table 2, column C). While such averages are somewhat useful in defining the problem, they can be misleading. A fuller understanding of the scope of the problem can be gained from summarization of bee loss data (Table 3) by states. Table 4 clearly shows the highly regionalized nature of bee/pesticide losses based on the percentage distribution of indemnity payments. Three states (California, Washington and Arizona) accounted for 52.7% of all indemnity payments (1967-78) and only these states and Georgia exceeded the national average.

An even more meaningful view is presented in Figure 1 where bee losses for the three year period (1976-78) are presented as the percent of colonies affected by state. It is interest-

Table 1. National Market values for honey bees and honey bee products for the years 1967-79 (Agricultural Statistics — 1980 p. 93)

Year	No. Colonies (x1000)	Honey yield/ colony (lbs)[1]	Price/ lb	Beeswax yield/ colony (lbs)[1]	Price lb	Productive value per colony[2]
1967	4635	46.6	$.156	0.95	$ .588	$ 7.83
1968	4539	42.2	.169	0.84	.616	7.65
1969	4433	60.3	.175	1.17	.611	11.27
1970	4285	51.7	.174	1.02	.602	9.61
1971	4107	48.2	.218	0.88	.613	11.65
1972	4085	52.8	.302	0.98	.621	16.55
1973	4124	58.0	.444	1.03	.744	26.52
1974	4210	44.6	.510	0.82	1.14	23.68
1975	4206	47.4	.505	0.81	1.03	24.77
1976	4285	46.3	.499	0.78	1.12	23.98
1977	4346	41.1	.530	0.71	1.58	22.90
1978	4081	56.5	.545	0.96	1.74	32.46
1979	4145	57.2	.590	0.90	1.75	35.32

[1] Yield per colony = lbs produced/no. colonies.

[2] Productive value per colony = (honey yield/colony x price/lb) + (beeswax yield/colony x price/lb).

Table 2. A national summary of the losses caused by pesticides to honey bees for the years 1967-78 based on bee indemnity payment to beekeepers.

Year	(A) Productive value per colony[1]	(B) Productive value (x1000) of U.S. colonies[2]	(C) % Actual loss[4]	(D) % Loss under BIPP[3]
1967	$ 7.83	36,292	5.2	5.0
1968	7.65	34,723	5.0	4.8
1969	11.27	49,960	5.1	3.3
1970	9.61	41,179	5.0	4.0
1971	11.65	47,847	7.4	6.7
1972	16.55	67,607	6.0	3.2
1973	26.52	109,368	5.0	1.6
1974	23.68	99,693	5.8	3.2
1975	24.77	104,183	5.8	2.9
1976	23.98	102,754	6.9	3.5
1977	22.90	99,523	8.4	4.4
1978	32.46	132,567	8.4	3.2
		Average	6.2	3.8

[1] From Table 1

[2] Productive value of U.S. colonies = (number of colonies x productive value per colony)

[3] % Loss under BIPP = Bee indemnity payments / productive value per colony

[4] % Actual loss = number of colonies damaged or destroyed x productive value per colony / number of colonies in U.S. x productive value per colony

ing to note that adjacent states often have very different bee loss profiles. In some instances we can presume that this is the result of cropping practices. For example, cotton is the single greatest source of pesticide hazard for bees. About one-half of all pesticides used for crop protection in the United States are applied to cotton. Thus, one can, with some certainty, conclude that cotton production accounts for the observed differences in the southern states. The reasons behind the differences elsewhere may be more obscure.

Further evidence of the regionalized nature of bee pesticide losses can be seen in ASCS data from Wisconsin, 1975-79 (Table 5). "Approximately 5-7% of Wisconsin honey bee colonies are affected annually by pesticides. This level of damage is . . . partially due to the agricultural practices peculiar to Wisconsin and to the fact that many colonies are kept in nonagricultural areas. Nevertheless, localized losses of bees due to pesticides are often severe. For example, estimated losses in those counties most severely affected have ranged from 40% (1,731 colonies in Columbia County, 1977) to more than 60% (2,463 colonies in Sauk County, 1979)." (Note: each state should summarize its losses in this fashion while ASCS records are still available.)

While we must remain aware of the dangers of oversimplification, experts generally agree that a limited number of widely used insecticides (primarily methyl parathion, parathion, carbofuran and carbaryl) are responsible for the overwhelming majority of our national bee losses. Similarly, the majority of these losses involve a limited number of crops that are widely grown (primarily alfalfa, cotton, orchard crops, sweet corn, and perhaps soybeans in some areas). Even though the broad perspective has changed very little in the past two or three decades, there are exceptional regions, such as the valley croplands of California where infrequently used pesticides combined with a diversity of crops create more complex problems. However, it seems that Wisconsin, where most bee kills (about 68%) have been caused by the use of three chemicals (Carbaryl, (Sevin®), Methomyl (Lannate®), and parathion) on sweet corn, typifies the problems found in most states/regions. Statewide these three chemicals caused 88 percent of all bee losses from 1975 to 1979. (Note: Although ASCS often reported losses on sweet corn as either Sevin or parathion, the control measure of choice is a tank mix of Sevin® plus parathion.)

One also sees short term trends in the evolution of farming practices. For example, from 1976 to 1978 the number of reported bee kills from methomyl in Wisconsin increased from 2 to 104 colonies while those from carbaryl decreased from 159 to 98.[13] These numbers probably reflect a transition from carbaryl to methomyl use on sweet corn in accordance with reports that the latter is less hazardous to bees. The view that methomyl is less hazardous to bees does not appear to be valid for Wisconsin (see Part II).

We would be remiss if we did not point out that bee loss data, such as losses reported under the BIPP, are, like all such surveys, inherently biased and incomplete. For example, it is extremely difficult to estimate the magnitude of unreported losses. Nevertheless, we know that such losses have occurred.[6] Neither do these data reflect the disruptive effect of pesticides on beekeeping; beekeepers have found it impossible to keep bees where pesticide use is high and have moved completely out of some areas. Finally, these data do not reflect long term

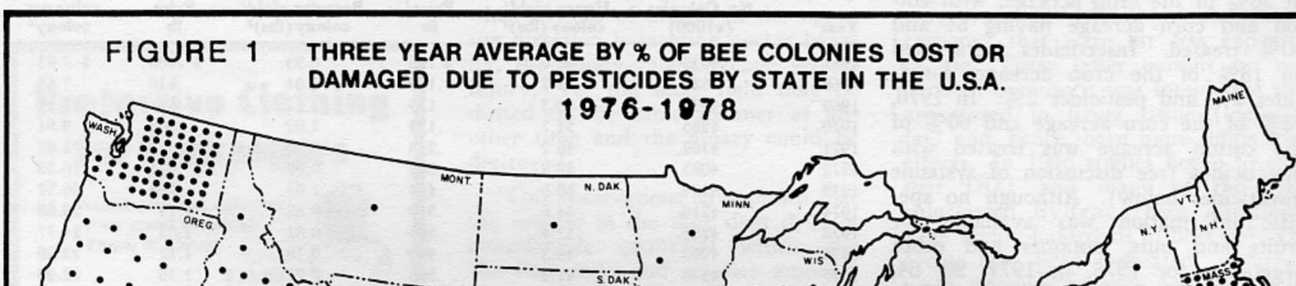

Figure 1. 1976 to 1978 average by % of bee colonies lost or damaged from pesticides by state in the U.S.

effects of pesticides involving sublethal residues in beehives and/or the environment and which ultimately reduce colony productivity and plant pollination. Nevertheless, data from the ASCS-BIPP and other sources do present a reasonable relative assessment of the fundamental problem components and should be used in the identification of regional (state) problems and in the development of priorities for solutions to the problem complex.

During the course of preparing this series of papers, several critical issues became apparent to us. As we move forward during the next decade, some or all of these issues need to be addressed before we can resolve the bee/pesticide dilemma. For instance, how do crop production and bee management practices differ for each commodity among states? What effects do the differing environments, both within and among states, have on the physiological response of the crops and their associated insect populations? Are beekeepers better informed about pesticides in some states than in others? How different are individual state regulations governing insecticide use around honey bees? These and many other questions readily come to mind as we begin to systematically analyze the pesticide problems.

Clearly, we in the 1980's continue to make many of the same mistakes that our predecessors made 40 years and more ago. Whether in research, extension or general agriculture we must aggressively seek new approaches or solutions to the pesticide related problems that beekeepers continue to face. This can only be accomplished with a more complete understanding of the precise nature of these problems. In Part II of this series we will attempt to present a biological perspective of the bee/pesticide situation.

Table 3. Damage to bee colonies in the United States for which indemnity payments were made under BIPP, calendar years 1967-78.

Year	Colonies damaged	Indemnity payments	Beekeepers receiving payments
1967	243,493	$1,806,237	370[1]
1968	228,781	1,662,600	390
1969	226,859	1,658,407	442
1970	215,272	1,661,207	469
1971	304,421	3,232,331	818
1972	247,265	2,178,086	647
1973	205,351	1,805,040	680
1974	243,608	3,207,879	984
1975	245,941	2,988,180	998
1976	295,037	3,614,396	1,307
1977	364,103	4,385,881	1,826
1978	344,443	4,262,266	1,624
1979[2]		1,221,919	-
TOTALS	3,164,574	34,298,195	

[1]Some beekeepers have received funds in more than one year. Source: ASCS/EIPD/3/13/1980.

[2]Shows only partial payments for claims filed due to inadequate funds available to pay all claims. No 1980 claims were paid due to lack of funding.

Table 4. Distribution of indemnity payments in the United States under BIPP, selected states and total, for calendar years 1967-78.

State	Indemnity Payments: Paid to state	Indemnity Payments: Percentage of U.S Total
California	$ 6,764,902	20.7
Washington	5,810,996	17.8
Arizona	4,627,040	14.2
Georgia	2,159,647	6.6
Idaho	1,553,664	4.7
Texas	1,322,863	4.0
Louisiana	1,235,948	3.8
Arkansas	1,234,047	3.8
Others	7,976,302	24.4
TOTALS	32,685,409	100.0

Source: ASCS/EIPD/3/13/1980.

Table 5. Bee losses in Wisconsin 1975-1979

	1975	1976	1977	1978	1979
Locations Affected	186	167	250	209	79
Colonies Affected	6,254	5,596	8.761	6,196	9,951
% of Colonies Affected	5.5%	4.8%	7.0%	5.0%	7.4%
Pesticides Responsible for Losses	**Number of Locations Affected:**				
Sevin (carbaryl)	101	159	215	98	36
Malathion	53	1	--	--	1
Lannate (methomyl)	20	2	18	104	11
Parathion	--	4	2	3	10
Other (Alfatox, Diazinon, Cygon, EPN, Furadan, paraquat, Supracide	12	1	15	4	21
Crops in Which Losses Occurred	**Number of Locations Affected:**				
Alfalfa	--	--	10	6	25
Cucumbers	2	--	2	--	--
Field corn	1	1	1	21	2
Green beans	6	14	13	7	3
Lima beans	1	1	--	1	--
Oats, corn, or hay	53	1	18	14	7
Peas	26	28	1	4	4
Sweet corn	96	120	197	153	36
Tobacco	--	1	6	--	--
Other (melons, potatoes, soybeans)	1	1	2	3	2

Source: Wedberg and Erickson (1980).

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Beekeeping Truisms

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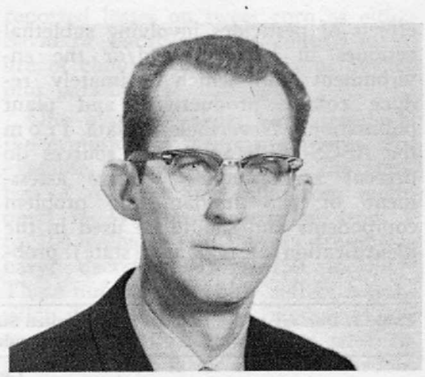

Truism

Preparedness is a major cost-saving factor.

Rationale

It is at least partly true that if you go to a beeyard without first knowing why you are going and what you are going to do when you get there, you may as well stay at home. With travel costs high as they are, the logic becomes readily apparent. If long distances are involved, preparedness is key to cost avoidance.

STANDARDIZATION of hive parts is critical. I once purchased some 8-frame colonies and added them to my 10-frame outfit. All colonies in any given yard were either one size or the other for a while. As I made increase, moved colonies to equalize yard size, moved colonies for pollination etc., I soon had some of both in some yards. Adequate preparedness soon became very difficult. When I loaded supers on the truck, it was very hard to have the right mix of sizes. Several extra trips resulted as I ran short of one size or the other.

For the commercial beekeeper a checklist is a must. The checklist can be a written list but can also be an "everything in its place" toolbox, a truck with specific compartments for smoker fuel, smokers, hive tools, ropes and other needed items.

It is most exasperating to arrive at a bee yard, enthused and ready to go, only to find that you have forgotten matches. Screwdrivers will get you by in a pinch and definitely help you appreciate the value of a good hive tool. One of the most expensive pieces of equipment to leave at home is a truck jack.

Being prepared means that every beekeeper should have his/her own management system. It is the blueprint by which your plans for an entire year of beekeeping are laid. It has the anticipated manipulations which you intend to use detailed with an approximate date for begininng and completion. The plan can be shifted forward or back as the season progresses to accommodate actual conditions, but it eliminates surprises to a great extent, which is extremely helpful in being prepared.

One year many of my bee colonies were in the orchards for pollination rentals. I hauled them into the orchards on a drizzly day. It began to rain in earnest and for most of 10 days was too wet to get a truck near them. The colonies were brooded up quite well. It became necessary to haul feed to them on a wheelbarrow. I was not prepared.

None of the feeding problems was included in my management plan. It was an emergency to which I had to respond quickly and with all the resources available. Shortly thereafter and before it was possible to get trucks into the orchard, the weather cleared. It warmed up and the fruit bloom which had been held back by the weather came on with a surge.

Sweet cherries, some varieties of peaches, pears, dandelions underneath the trees and the early varieties of apples were all on at once. Some were coming on and others were near the end of their blooming period, but all were on together.

Colonies which had become very light began to fill with nectar and pollen. One of the very best spring nectar flows I have ever experienced soon had all colonies heavy and ready to divide for increase. My management system was soon back on schedule. The bees could be returned to their permanent locations where the actual dividing was done.

Records kept from year to year are invaluable in setting management plans. At first, the most striking thing about records of the blooming dates of major honey plants is the variance in the time of bloom from year to year. Records kept over many years, become more impressive because of overall constancy of bloom periods.

Being prepared with an adequate amount of tops, bottoms and supers helps avoid the day and night, backbreaking labor of playing catch-up to swarm prevention manipulations and honeyflows. I am always disgusted with myself when caught short. Preparedness is a major cost avoidance technique in a business so labor and travel intensive as beekeeping. **(Next month — A beekeeper's success lies first in his head and second in his hands.)** ●