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Pollination of Citrus by Honey Bees[1]

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Over the last five decades, considerable research has improved production practices, resulting in ever increasing yields and quality. Generally these have consisted of adding nutrients (fertilization), applying a number of chemical controls for pests (fungicides, insecticides, herbicides), as well as implementing other cultural practices demanded by the crops themselves and/or the environmental conditions under which they might be produced.

All too often forgotten, however, has been study of the effects of pollination and pollination practices on crops. It is easy to understand why pollination has been neglected; as an open system, it poses more difficultly than closed system research where inputs and outputs can be readily measured. In addition, the need for such research is difficult to ascertain because resulting increases in quality and quantity from other cultural practices have acted to mask the possible contribution of pollination. The cultural practices mentioned above, however, especially those surrounding application of pesticides, are now reaching points of limited and in some cases, diminished returns. It is, therefore, fitting to reexamine the role of pollination as a practice whose time has come.

This paper will address the current thinking on pollination research in general and in specifics about citrus culture. In addition, it will examine some of the present and future possibilities about the value of the honey bee to this valuable crop.

Over a decade ago, Dr. Marshall Levin, now head of the Carl B. Hayden Bee Laboratory, Tucson, Arizona analyzed the status of pollination research in his paper, "Whither Pollination-Research and Practice," published in the Proceedings of the Ninth Pollination Conference, Hot Springs, Arkansas. He indicated then that most prior pollination research by was opportunistic, only accomplished at those rare times when apiculturist and crop specialist could work together. However, he was gratified to see a trend that more and more persons were taking an interest in pollination.

Dr. Levin further suggested that pollination research traditionally dealt with requirements and responses of the plant, such as (a) determining the pollination requirements of various crops, (b) determining how those requirements are fulfilled, (c) breeding plant lines incorporating elements contributing to increased pollination efficiency and (d) developing cultural practices to ensure adequate pollination. However, he saw a new focus. Researchers were taking a closer look at the pollinators themselves, especially honey bees and studying (a) plant and environmental factors that affect the bee's pollinating activities, (b) influences of bee genetics on foraging and selecting behavior, (c) effects of the physical status of a bee colony on its pollinating effectiveness and (d) beekeeping practices which improve pollinating effectiveness.

In spite of Dr. Levin's optimism at that time (1970) that pollination research was becoming more important, implementation has been spotty. Some twelve years later at the Tenth Pollination Conference, Carbondale, Illinois there

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was evidence of new trends in research, focusing principally on commercial hybrid plant production, but traditional agricultural crops were virtually ignored. The message seems clear, pollination research continues to languish on the back burner. There are still many questions and few concrete answers about either pollination requirements for certain crops or specific management practices surrounding their insect pollinators.

This is certainly the case for citrus, even though this crop has been studied more perhaps than others. This does not mean that no good information exists on pollinating citrus; a number of studies over the years have tackled the problem. However, much remains to be done and controversy continues about the pollination potential of bees and possible management strategies required to ensure adequate pollination of the citrus crop.

It is difficult to issue hard and fast recommendations about citrus pollination for a number of reasons. There exists a number of citrus varieties and more are being developed all the time. Each has its own characteristics that must be addressed in order to assure adequate pollination. Recommendations for grapefruit will differ from limes which will differ from oranges. In addition, a good many variables exist under field conditions which often do not mirror those of controlled experiments.

A host of plant-environment-pollinator interactions also comes into play, many of which are not well understood. Increasing knowledge about both plant communities and pollinator populations can also change the focus of recommendations and research priorities. Finally, economic considerations may also dictate that issues of relatively small importance in the past may become overriding concerns in the future.

From a growers present perspective, information on citrus pollination may seem academic. After all, beekeepers continue to clamor for citrus grove locations. Most citrus is, fortuitously for growers, superior in nectar production, responsible in good years for a premium, high quality honey crop. Thus, there are always plenty of bees in the groves; whatever pollination is needed is right at hand. And best of all, it's provided free for the producer in exchange for nectar that would otherwise go to waste.

This has led to the conventional wisdom that pollination in most citrus is not really required. Other evidence contributing to this belief, as published by Dr. A. Krezdorn, retired from the Institute of Food and Agricultural Sciences (IFAS), University of Florida, "*Pollination Requirements of Citrus*," Report of the Ninth Pollination Conference, Hot Springs, Arkansas, include:

1. Citrus flowers are perfect, having both sexes on the same blossom so that self-pollination takes place regardless of pollinators. But bees (pollinators) are distributed throughout citrus groves in any case.

2. Female-sterile varieties are not benefited by pollinators.

3. Some seedless varieties may benefit, but evidence is lacking.

However, Dr. Krezdorn does suggest that this by no means indicates pollination is not necessary in citrus. For example:

1. There is a growing number of citrus varieties which require cross pollination because they are self-incompatible.

2. A positive linear relationship between fruit size and number of seeds per fruit exists.

3. Where cross pollination is required, use of honey bees remains the most consistent, effective and economical means of ensuring adequate yields.

Another look at the requirements for citrus pollination comes from Agriculture Handbook 496, by S.E. McGregor, "Insect Pollination of Cultivated Crop Plants," published in 1976 by the Agricultural Research Service. The volume treats citrus separately by group.

Grapefruit: Although consensus suggests pollination is not required, there is evidence that open pollination benefited at least one variety (Marsh) by setting four times the fruit which had twice the number of seeds.

Lemons: Russian literature is cited which indicates lemons benefited from pollination. This is in opposition to most U.S. studies indicating the value to be minimal. However, there is evidence that seedlessness can result from self pollination, and that seedlessness may contribute to a reduction in fruit set.

Limes: Few studies have been done. One suggests limited pollination benefit from bees on Tahiti lime which is strongly parthenocarpic. Another suggested sweet limes would benefit from pollination by setting up to twenty percent more fruit.

Oranges: A large variation between cultivars exists in oranges making any sort of general statement difficult. Studies on certain varieties, however, have been accomplished:

- **Washington Navel**: Although it has been suggested that cross pollination on Washington Navels is not required to increase yield, there is evidence to show that pollination by bees may contribute to less fruit drop.

- **Valencias**: Most investigators contend that this variety benefits little from pollination by bees. One study, however, indicates fruit size was increased as the seed number increased.

- **Other sweet oranges**: Not much study has been done on these, but there is some indication that pollination is beneficial. It has also been suggested that reduced fruit set in so-called "off years" may be offset by honey bee pollination.

- **Pummelo**: This variety appears to be grown commercially only in the Orient and is self-incompatible. Evidence suggests that pollinating by bees is important whether the plant is self-fertile or self-sterile.

Mandarin and Mandarin-Hybrid Complex: Many varieties of this complex are self-incompatible and require pollination. Because pollination is more critical, much more research has been done on this group than others. For Florida, Dr. Krezdorn has published a list of varieties and their characteristics as shown in Table 1.

In summary it may be concluded that honey bees are unquestionably important in the pollination of citrus, though some varieties benefit more than others. In addition, there is the belief that ample quantities of bees are always present in groves because of their rich nectar resources so that pollination becomes academic. Major questions, however, remain concerning the distribution of bees in groves and possible management to optimize their pollinating activities.

There is evidence that uniform populations of honey bees cannot be taken for granted. Beekeepers and others have noticed from time to time that some areas are over crowded with bee colonies whereas others go wanting. There is also evidence of a zonal distribution of bees, based on distance of trees from hives (Butcher, 1955). Professor Frank Robinson, retired, IFAS, University of Florida, however, takes exception and has stated (1958) that bees worked equally well in all directions and were evenly spread to 400 feet. Personal communication with others by this author and evidence from studies of other plants suggests that bees frequently distribute themselves unequally, for example, preferring to fly along individual rows rather than across rows.

It is not surprising to find differences of opinion throughout the literature. The number of variables that come into play are legion and one or a dozen studies could not possibly take into account all the possible permutations. Just a few include: (a) health or status of a bee colony, one of nature's most complex insect societies, (b) effects of nearby colonies and/or competing plants, (c) number of acres of plants present, as well as size of trees and number of blooms per tree, (d) physical care given to the grove (irrigation, fertilization) and (e) range of environmental conditions possible. The latter situation is perhaps the most difficult to deal with. It is well known in apicultural circles that observations over a number of seasons are necessary in order to critically assess data gathered on bee colonies.

Although science can suggest ways to improve cultural practices and provide guidelines to maximize agriculturalists efforts, the ultimate confirmation can only come from success by the entrepreneur in the field. This is equally true in both the apicultural and citrus industry. From a practical standpoint, the agriculturalist must try to emulate the scientist by attempting to control as many of variables as possible and then develop conclusions from his/her own experimentation and observation.

By acquiring pollinating colonies of bees for the citrus groves, the grower gains a greater degree of control than is possible otherwise. He/she can determine among other things: (a) distribution of colonies throughout the grove, (b) strength of pollinating units per unit area, and (c) time of entry of colonies. All these can make a great difference in ensuring adequate pollination. Adequate pollination should be viewed as an insurance policy of sorts. There is evidence that citrus in general sets a small percentage of fruit over blossoms available (Reuther et al., 1968) and that certain varieties exhibit biennial bearing (Moss, 1971). Ensuring that enough honey bees are available in order to set the maximum fruit possible makes as much sense as irrigating to provide adequate moisture or applying pesticides to control loss through competition.

The Florida Citrus-Bee Industry Connection is an excellent example of symbiosis (Sanford, 1985). However, like most mutually beneficial relationships, it is tenuous and constantly changing. In the past, citrus growers have had the luxury of a large number of beekeepers soliciting locations in groves. As a consequence, those in the research establishment have stated that because bees are or will always be present in groves, adequate pollination is of little concern.

Events of the 1980's, however, may radically change this assessment.

The apicultural industry is in trouble. Contributory to this in Florida is that citrus honey production has been off for several years in a row, denying needed income. Of more importance, the industry's major product, honey, has been and continues to be unprofitable to produce. Costs continue to be greater than market prices. The industry has suffered severe erosion of its markets from use of artificial sweeteners and inexpensive corn syrups. Finally, honey imports into the United States over the last decade have increased to the point that over half the nation's honey crop last year was delivered as surplus to the Commodity Credit Corporation.

Discovery of the honey bee tracheal mite in 1984 has added further to the confusion; there is evidence that quarantine and regulations have done a great deal of damage to an already fragile industry. Changing land use patterns in Florida also have negatively affected many beekeepers. Prime bee locations are becoming more difficult to find because of large-scale agriculture and urbanization. Beekeepers need areas of sanctuary to move their bees during periods of nectar dearth or pesticide application.

On the horizon, two events promise to bring more havoc: (a) introduction of the Asian Mite and/or (b) arrival of the Africanized honey bee. The former is responsible for deaths of many colonies throughout the world and demands costly management to control infestation levels.

The Africanized honey bee is a special case. Experience has shown that where the Africanized honey bee has become established in Latin America, the beekeeping industry has been destroyed for a period of years, although most have or are recovering. If as expected, establishment of the bee results in a great many more wild or feral swarms which compete vigorously for nectar, this will mean even less resources for managed colonies. In addition, growers may well be placed in the position of aggressively destroying feral nests in their groves to protect their workers or the general public. The beekeeper with his/her specialized knowledge may become a valuable ally in this endeavor. The beekeeper will need as many friends as possible if the Africanized honey bee becomes the public health hazard some have prognosticated. Locations may become impossible to obtain near urban areas, further contributing to a decline in managed bee colonies.

The present economic situation and grim prospects for the future have already resulted in a record number of beekeepers going out of business. In addition, there is evidence that few younger people are willing to invest money and labor in beekeeping because of low returns and threats posed by the Asian mite and Africanized honey bee. What this means to the traditional Florida Citrus-Bee Industry Connection is only guesswork at the present time. However, it is entirely possible that in the near future there will not be enough beekeepers to provide the same numbers of bee colonies in citrus groves as have been present in the past.

One hedge against bankruptcy by beekeepers is the possibility of increasing pollination fees. For many, this means charging for services that, heretofore, they have provided free. It also means providing services instead of producing and processing a crop, in essence another kind of endeavor for which many are not presently suited. The citrus grower may be in a unique situation to help beekeepers make the transition from sole reliance on honey production to providing pollination services.

There is precedent for this. As Dr. Levin said in his address to the Ninth Pollination Conference:

- In a few instances, growers have been more progressive and have literally forced changes on the beekeepers. For example, the demands of the alfalfa seed growing industry expedited the development of hive hoists. The seed industry took the lead in commercial utilization of the APC (Alfalfa Pollen Collecting) strains of bees. Grower insistence has often overridden the natural inclination of beekeepers to place their colonies in large groups, and the result has been the distribution of colonies in many small groups for maximum pollinator dispersion. The use of pollen dispensing entrance inserts, too, has more often been espoused by the grower than the beekeeper.

In the past, pollinating services have been looked at opportunistic at best and at worst, a necessary diversion of resources from honey production. This attitude and the low fees many growers grudgingly paid contributed all too often to the concept that providing pollinators was a second-rate business. Many beekeepers contributed to this by undercutting pollination prices of their colleagues and by using substandard pollinating units, taking unfair advantage of the grower's limited knowledge about honey bees.

The pollinating business must be recognized for what it is, a valuable service important to agriculture. The future basis of this will be honest communication between beekeeper and grower. The beekeeper must educate the grower as much as possible about honey bees, bringing to the relationship experiences in managing honey bees. And the grower should reciprocate with his/her knowledge

about specific cultural practices necessary to optimize both quantity and quality yields.

In today's business climate the best way to promote communication and cooperation is through written contracts. Although this may be viewed askance by many as not traditional, it can avoid a great many problems. According to Agriculture Handbook 496, a good pollination contract has many elements and will vary considerably between crops and individuals, but usually consists of the following:

1. Identifying the participants to the contract (grower and beekeeper).

2. Deciding on a price and when and how payment should be effected.

3. Determine the time of delivery (often critical to both grower and beekeeper).

4. Stating the number of colonies and their strength. Little can be concluded by looking at the outsides of a beehive. Thus, numbers of colonies is not a good measure of pollinating potential. It is imperative each colony be opened and examined for:

5. Stating placement of colonies (most crops will get better coverage if colonies are spaced apart). For citrus, an interval of 1/4 to 1/3 mile between colonies has been recommended.

6. Stating operation and maintenance of colonies.

7. Determining when to remove colonies.

8. Determining liability for stings, pesticide application, etc.

9. Stating penalties, rewards and arbitration, if deemed necessary.

The future of agriculture appears to hang on a thread for a number of reasons over which farmers appear to have little control. Times of stress and great change, however, are also ripe for opportunity. The citrus grower and the beekeeper must continually reexamine their relationship within the context of the 1980s and determine the direction needed to maintain their mutually profitable relationship. If successful, they have the opportunity to become leaders in the new agricultural scene. Failure can only result in eventual economic as well as emotional bankruptcy, something modern society cannot afford.

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Table 1.

. Characteristics of Citrus Varieties and Need for Bees			
Variety	Sexually Incompatible	Parthenocarpy	Bees Required
Dancy	No	Very Weak	No
Temple	No	Very Weak	No
Orlando	Yes	Weak	Yes
Minneola	Yes	Weak	Yes
Robinson	Yes	Weak	Yes
Osceola	Yes	Weak	Yes
Nova	Yes	Weak	Yes
Lee	?	?	?