POLLEN GATHERING BY HONEY BEES IN SOUTHERN MICHIGAN

Thesis for the Degree of M. S.
MICHIGAN STATE UNIVERSITY

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1975

ABSTRACT

POLLEN GATHERING BY HONEY BEES IN SOUTHERN MICHIGAN

By

Larry Gene Olsen

O. A. C. pollen traps were placed on honey bee colonies to determine major sources of pollen in southern Michigan. Once trapped, pollen samples were weighed and acetolysed prior to identification. Scanning electron micrographs aided in identifying the major sources.

At the Michigan State University apiary, the major sources of pollen for 1970 and 1971 were goldenrod, aster, alsike clover, and white clover. Certain other species provided more pollen than anticipated (i.e. sumac, corn, Queen Annes lace, and burdock) while others proved to be less important than expected (i.e. dandelion).

Two hybrid races of bees were compared for pollen gathering tendencies. Generally they gathered the same amounts of pollen from the same plant species. However, under the conditions of this test, Italians gathered significantly more pollen from corn, Queen Annes lace, red clover, and ragweed and less from sow thistle, white clover, aster, and bull thistle than Carniolan colonies.

A study to determine time of day bees gather pollen from specific sources revealed most pollen sources present their pollen throughout the day. Specific differences did occur as corn, charlock, sow thistle, Queen Annes lace, and ragweed were gathered significantly more in the

morning and aster, burdock, sweet clover, bull thistle, and red clover were worked for pollen more in the afternoon.

In 1971, seasonal patterns of pollen gathering at four sites in southern Michigan were determined. At each site different species provided the greatest amount of pollen, but goldenrod and clover were most prevalent. Fifteen species provided two-thirds of the pollen gathered at these sites.

Plants which compete for bee visits to pollinated crops was studied briefly by trapping pollen from colonies placed in the target crop during bloom. Apples appear to compete well for bee visits with other plants which bloom at the same period. Minor competitors were yellow rocket, dandelion, and honeysuckle. Blueberries do not compete well for pollen collecting bee visits. Many plants in the vicinity can provide more pollen, but good pollination is nevertheless accomplished by bees working blueberries for nectar. Strawberries compete well for pollen gathering bees but tree fruits, willow, dandelion, and yellow rocket pollen was gathered. On the average, the percentage of strawberry pollen gathered by honey bees was higher in the afternoon than in the morning. Redchief variety rated low in attractiveness to honey bees. Bees are effective pollinators of cucumbers; however, no cucumber pollen was collected in the traps. Depending on location of the fields and date of bloom, several plant species can provide the majority of pollen.

The periodicity of pollen flow was studied in southern Michigan. Factors which may have an influence on the amount of pollen gathered such as honey flow, brood area, and population size were studied. Honey flow over three years indicated that peak nectar collection in mid-summer coincided with the low point in pollen gathering in East Lansing suggesting bees switch to nectar gathers during peak honey flow. Colony strength measurements of brood area and population size indicated that no differences occurred between the two races. This explained the results that both the Italian and Carniolan colonies gathered the same total amount of pollen. Both races gathered significantly more pollen in the morning than afternoon until early September, and after that significantly more in the afternoon as a result of morning temperatures being too cool for active bee foraging. Differences did occur in pollen flow at different locations, with the predominance of local flora determining the amount of pollen gathered. Generally the flow peaked during June, then diminished until late October.

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BY

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Entomology

1975

ACKNOWLEDGEMENTS

I would like to relay my sincerest gratitude to Dr. E. C. Martin for his exceptional patience and direction in the preparation of this thesis. His constant encouragement led to the belated completion of this manuscript. Without his guidance and suggestions this would not have been possible.

I would also like to thank Dr. Richard Sauer, Dr. Stanley Wellso, and Dr. Roger Hoopingarner for serving on my guidance committee and reviewing this thesis.

Thanks are extended to Mr. William S. McAfee and Dr. William Roberts. Mr. William McAfee was in the Department of Botany and Plant Pathology operated the Advanced Metals Research 900 Scanning Electron Microscope. His work allowed the preparation of the SEM photographs of the pollen found in Appendix I. Dr. William Roberts at the USDA Bee Breeding Laboratory in Baton Rouge, Louisiana supplied the hybrid queens used in this study to determine racial differences in pollen gathering.

I would like to thank Mr. Ernest and Mike Connor, Mr. Joseph Howard, and Mr. Raymond and Eugene Montegue for their cooperation in collecting pollen samples weekly throughout the summer.

Thanks are extended to the Department of Entomology for the supplies and equipment I used and to Dr. Gordon Guyer for the office space. Thanks also to Dr. E. C. Martin for his financial assistance for myself and the people who aided in my research.

I would like to thank all those who helped during the summer and especially Dan Collar, Abby Edwards, Dale Maki, Carl Stephens and Dan Young who assisted me for many hours in sorting the pollen samples and running the acetolysis process so identification could be performed, and for determining colony strength measurements by calculating brood area and estimating colony populations. Thanks lastly to Abby Edwards and Jean Van Douser for their many hours of typing.

Special thanks to Dr. Lawrence Connor and Mr. Clarence Collison for their suggestions on research design and data analysis. Without their encouragement and consultation much of the data would have been improperly analyzed.

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INTRODUCTION

Honey bees are one of the most highly evolved insects. Reasons for this are their ability to communicate, the young live with the parent and provide for the next generation, and a division of labor exists between and within castes. These insects have the remarkable ability to communicate with each other such things as distance and direction to food sources, conditions within the hive, and alarm situations. When the bees are foraging, they have a unique trait of visiting a single plant species until they have a full load. From this plant either nectar is gathered for immediate energy or stored for future use in the form of honey, or pollen is gathered, providing protein for larval development and adult maintenance. This study takes advantage of this constancy phenomena and monitors which plants are visited by honey bees for pollen, and identifies the relative importance of each plant species to the colony.

Information on pollen sources is needed for several reasons. First, is the need to know the species of plants which supply pollen to bees and which plants are most important to the colony. In this modern age of the metropolis, wild lands are decreasing and cultural practices such as the expanding use of pesticides, extensive area of monoculture and clean cultivation may eliminate whole species of native bees that play such an important pollination roll. It has become necessary to know what plants are required in good bee pasture to maintain an adequate pollination force to pollinate our crops and wild flowers.

Besides the basic research of identifying the major pollen sources, several other objectives have been pursued:

1. Develop a phenological chart of the plants that are visited by bees in search of pollen at some Michigan locations.

2. Assess possible differences between races or strains of bees in flower preferences.

3. Determine the time of day bees gather pollen from different sources.

4. Determine the relative importance of different pollen plants in several locations.

5. Identify the major plants competitive with some bee-pollinated crops.

6. Determine the periodicity of the pollen flow throughout the season by weighing trapped pollen.

7. Build a set of reference slides of pollen of known plants prepared by the acetolysis and I.U.B.S. methods. Supplement these slides with SEM photographs of the major pollen plants.

8. Assess the data for the development of practical knowledge and recommendations on such things as: locating apiaries in most advantageous locations for pollen supply; suggested use of pollen plants for private land, diverted acres or park areas; indicating the best time of year to trap pollen for supplemental feeding; timing spray applications to avoid killing pollen-collecting bees; indicating the possibility of breeding bees for pollination of specific crops; influence of competitive plants to crop pollination; preliminary data for pollen analysis of Michigan honey; and relationship of pollen flows to bee behavior, management and wintering.

CHAPTER I

COLLECTION AND IDENTIFICATION OF BEE-GATHERED POLLEN

INTRODUCTION

Pollen was trapped from honey bee colonies in an effort to identify pollen sources. This identification was made by color comparison of the pollen pellets and microscopic comparison of pollen grains. All pellets from a single plant species are very similar in color; therefore, preliminary identification by color comparison to reference pellets can be made. Exact identification was made by comparing pollen grains from unknown pellets to reference slides of known pollens.

LITERATURE

The literature contains many references to methods and aspects of trapping and identifying bee-gathered pollen, and several of these will be referred to throughout this manuscript. Several authors have undertaken basic studies of bee-gathered pollens, e.g., Hare and Vansell (1946); Hodges (1958); Louveaux (1954); Maurizio (1953); Parker (1926); Percival (1947); and Riedel (1965). Their objectives were dissimilar but all authors agreed that identification by comparing unknown trapped pollen with reference pellets and slides of pollen grains was acceptable. These authors used several types of pollen traps to collect their samples, but the O.A.C. (Smith, 1965) trap was found the most adaptable and useful for our purposes. Once trapped, pollen was identified using procedures of Riedel (1965), but modified to include the acetolysis process described by Erdtman (1969). Further refinement of identification was accomplished by using Scanning Electron Microscope photographs of known pollen grains (Martin, 1969).

METHODS

TRAPPING POLLEN SAMPLES

Bee-gathered pollen was trapped from colonies for three seasons in an effort to determine major sources of pollen and the periodicity of the pollen flow throughout the season. Independent of the pollen trap used, the problem of variability of pollen pellet size existed. Weather conditions, season of year, colony needs, and ease of collecting and packing the pollen all effect pellet size. If pellets of a particular species were consistently small, they may not have been scraped off as the bee passed through the trap. Thus, the trapping method may not have given an entirely accurate picture of pollen sources. Vansell and Todd (1948) said: "A trap does not remove all the pollen, but its yield indicates the available field supply." In this study a truly representative sample may not have been obtained in all cases, but enough pollen was sampled so that a representative sample of the trapped pollen was obtained.

Pollen Traps - Pollen was trapped from honey bee colonies with the O.A.C. pollen trap (Fig. 1). This trap was placed on the bottom board below the hive bodies (Fig. 2), and as bees entered the hive they passed through a double layer of five-mesh to the inch hardware screen. This size mesh allowed the bee to pass through but its legs laden with pollen pellets were so wide that the pellets were scraped off as the bee entered the hive. The pellets fell into a tray that could be pulled out from the rear of the colony to collect the samples. This trap had the advantage that the five-mesh grid could be removed without removing the entire trap, allowing the bees full access to the gathered pollen, and the colony to recuperate if trapping had been excessive. It also had a slot which allowed drones to pass through.

IDENTIFICATION OF POLLEN PELLETS

Sorting Pollen Pellets - After pollen was collected from the hives according to the particular schedule followed in each study, samples were labeled by date and location and brought to the Michigan State University Apiculture Laboratory for identification. When received in the Laboratory, samples were weighed in grams (Fig. 3), a subsample saved, and the remainder stored by either freezing or mixing with sugar to be fed to the bees in spring. Subsamples of 300 to 400 pellets were sorted by color and size (Fig. 4). The number of pellets of each color was recorded, and the percentage of each color of the total sample was determined. A representative pellet was selected from each sorted sample for microscopic identification.

Reference Pollen Pellets - Honey bees working known plants for pollen and carrying pollen pellets on their legs were collected in the field and returned to the Laboratory to be used in identification of unknown trapped pollen. The plants on which the bees were collected were identified to species and mounted on herbarium paper for future reference. Plant identification was made by the author or the M.S.U. Herbarium staff, if doubt of identity existed. The bees were pinned

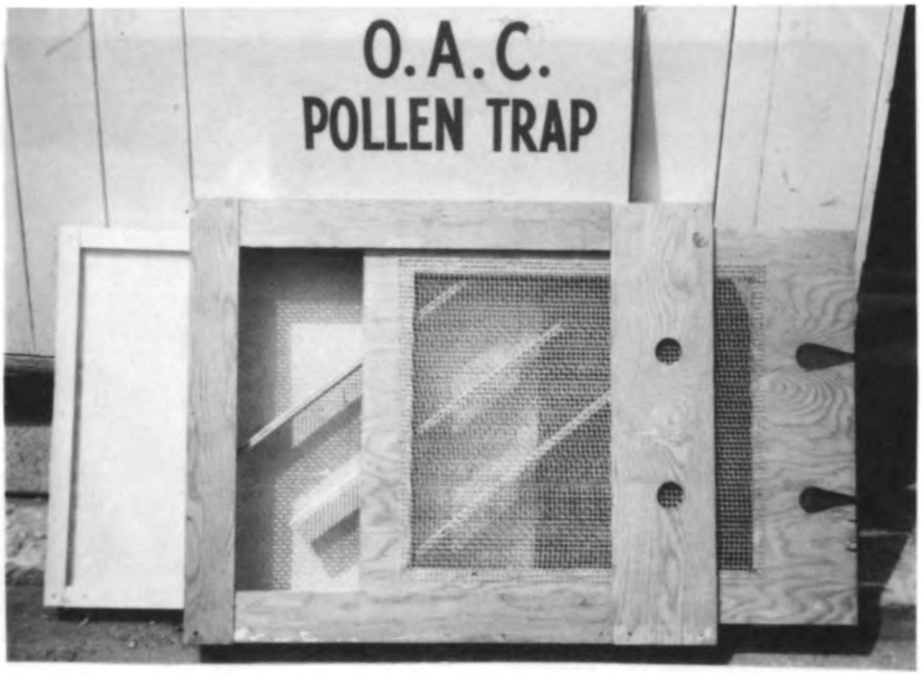

Fig. 1. The O.A.C. Pollen Trap Used to Collect Bee Gathered Pollen.

Fig. 2. The O.A.C. Pollen Trap in Position on a Colony.

Fig. 3. Pollen Samples Being Weighed and Subsampled for Identification.

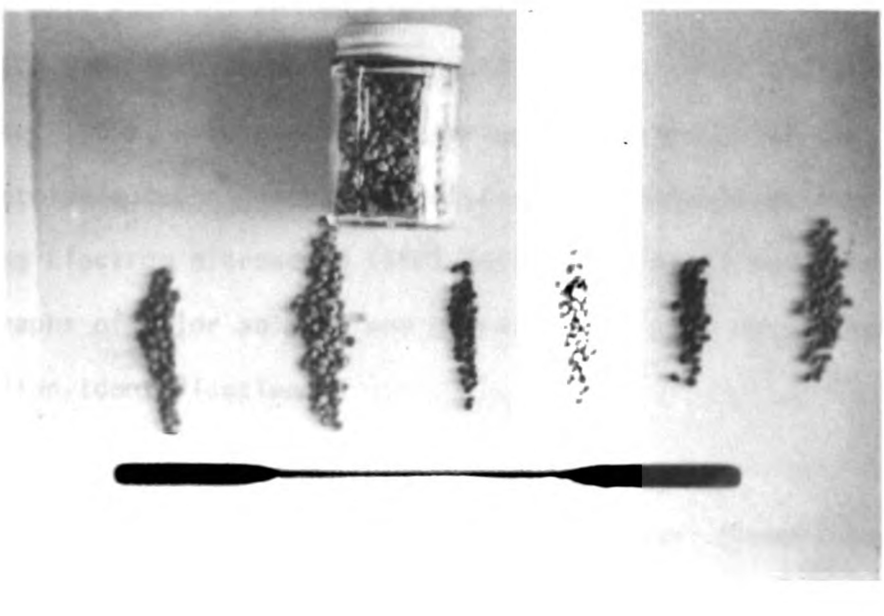

Fig. 4. Pollen Sampled Sorted into Groups According to Color and Size.

and the plant on which they were working noted on the label. These known corbicular pellets were used as standards for color, size and shape comparison with the unknown pellets. Preliminary identification was made by comparing unknown trapped pellets with these reference pellets. Identification problems arose at certain times of the year when pellets of nearly the same color were collected. Examples of this were: canada and bull thistle, white and alsike clover, white and yellow sweet clover, and goldenrod and aster. Therefore microscopic examination of many pollen grains became mandatory for accurate identification.

Reference Pollen Grains - In order to identify local plants by their pollen grains, a set of reference slides was prepared. This was necessary because palynology is a relatively new field and comprehensive keys of local pollen grains are not available. Two techniques, I.U.B.S. (Louveaux, Maurizio and Vorwohl, 1970) and acetolysis (Erdtman, 1969), were used in preparing the reference slides, with the acetolysis technique being preferred. Subsequently, the Scanning Electron Microscope (SEM) became available, and a set of photographs of major pollens was prepared which are very helpful for pollen identification.

I.U.B.S. - The International Commission for Bee Botany's method of preparing reference slides requires using fresh flowers and preparing slides of the pollen as it comes from the anthers. It basically consists of freeing the pollen from natural oils with a drop of ether and adding glycerin jelly and a cover slip for a permanent mount. Many slides were made using this method; however, a serious drawback was the difference in appearance of pollen grains obtained from fresh flowers compared with those in pollen pellets. When pollen pellet slides were prepared by the I.U.B.S. method, clumps of pollen grains remained stuck together and very few grains could be separated sufficiently for examination. There was also a differential uptake of the solvent, and individual grains would expand giving an uncharacteristic appearance. Lastly, the natural wax, oil, or other dissolved material would cover individual grains concealing the surface sculpturing required for identification.

Acetolysis - The second method of preparing reference slides was the acetolysis method modified for working with bee pellets. This proved to be more time consuming, but the results were greatly superior. The step by step procedure is explained in Table 1 with new techniques underlined. The chemical process involved dissolves all organic materials externally and internally associated with the pollen grain and leaves just the hard outer shell called exine. This method has two drawbacks in that thin walled pollens, e.g., bladdered conifers become less rigid and may collapse and pollen grains with opercula will loose them. However, all morphological features (apertures and sculpturing) were clearer and the method had a slight staining effect which made identification easier. Permanent slides of these pollen types were prepared for future reference.

SEM - Another tool useful for pollen identification was the Scanning Electron Microscope (SEM). This instrument was valuable in studying the external morphology and sculpturing of pollen

Table 1

Acetolysis Process for Preparing Bee-Collected Pollen Pellets

1. Place numbered samples of pollen in centrifuge tubes. Record the number on the centrifuge tube. (The amounts of the materials used below are for 4-6 pollen pellets; for one or two pellets use half the amounts stated.)

2. Add 5 ml. of glacial acetic acid to the pollen. Pollen may be stored in this manner for several months. Stir to break up the pellets. Centrifuge at 2400 rpm for 5 minutes and decant into sink. Keep centrifuge tubes balanced in weight.

3. Add 5 ml. of mixture of 9 parts of acetic anhydride with 1 part of conc. sulfuric acid to each tube. Heat in a boiling bath with care using a shield and fume hood for 3 minutes. Stir a few times while heating. Add 5 ml. of glacial acetic acid to stop the reaction. Centrifuge and decant the acetolysis fluid into the sink rinsing with excess water. Use care.

4. Wash with 5 ml. of distilled water. Centrifuge and decant. Repeat washing with distilled water.

5. If staining is desired for better structural contrast, add two drops of stain and boil in a water bath for 3 minutes. Centrifuge and decant. Wash with distilled water. Centrifuge and decant. Safranin-O is a good stain to use. To prepare mix 100 milligrams of Safranin-O in 1 cc. of glacial acetic acid and 100 cc. of distilled water.

6. Slides can now be prepared by placing a drop of the pollen solution and a drop of melted glycerin jelly on a slide. Stir this and add a cover slip. Keep level until the glycerin jelly has set, at least 15 minutes.

7. If remaining pollen solution is to be saved for future use, add 5 ml. of a mixture of glycerin-water (50:50). Leave for at least 10 minutes. Centrifuge and decant. Add 1½ to 4 ml. of glycerin. Stir and heat to 140°F. to facilitate pouring into numbered vials for numbered stock material.

8. Make slides from the stock material whenever wanted.

grains. Its use here was to provide a series of photographs of pollen grains of the principal Michigan pollen plants, to aid in the identification of unknown trapped pollen. Pollen to be photographed was obtained from corbicular pollen of bees working a known plant species. All pollens were acetolyzed before being photographed to allow the best possible view of the sculpturing and apertures and to reduce the chance of cracking upon prolonged exposure to the electron beam. The pollen was placed on double sticky tape on aluminum pedestals and coated with carbon and gold-palladium. An electron beam was focused on the pollen, and the secondary electrons were transmitted to a cathode-ray screen where line by line a picture was created. Larger pollen grains were viewed and photographed at 1,000x and the remainder at 2,000x.

Identification - Preliminary identification of sorted pollen pellets was made by comparing the colors of unknown pellets to colors of pellets from bees working known plants. Identification was made by taking a representative pellet from each pile of sorted pellets, acetolyzing it, and preparing a slide of it. The slide was then compared microscopically to the reference slides, and to the SEM photographs. Once identified, the percentage of the total for each subsample was calculated and recorded.

RESULTS AND DISCUSSION

Pollen Traps - During this study, three types of pollen traps were tested. Two of these were front entrance traps that proved to be undesirable and the other the O.A.C. trap. The front entrance traps were efficient in removing pollen from the bees corbicula, however, moisture collected in the holding tray and dissolved the pellets on many occasions before they were collected. Even though minor problems were encountered with the O.A.C. trap, it was far superior to the front entrance traps and should be used in further studies involving pollen collection.

SEM - The results of the SEM work are shown in the Appendix. Photographs are shown of the major pollen types along with notes of the nomenclature, magnification, size, and some diagnostic morphological features are presented. While observing the Canada Thistle preparation, a split grain appeared (Fig. 22) in which an interesting view of the pollen wall layers may be seen on the photograph.

CHAPTER 2

CALENDAR OF POLLEN PLANTS IN EAST LANSING

INTRODUCTION

The main purpose of this phase of the study was to identify and develop a phenological chart of the plants that are visited by honey bees in search of pollen at a particular location. An attempt was made to determine the relative importance of different pollen sources to the colony each week throughout the season.

LITERATURE

By knowing the succession of bloom of honey and pollen plants, a beekeeper can at a certain time perform such beekeeping practices as: installation of package bees, division for swarm control, adding supers for optimum production, or removal of honey to avoid unfavorable color or tasting honey. Several investigators have studied pollen sources by different methods to determine the succession of bloom in their immediate area. Percival (1947) recorded the plant blooming sequence from April 28 until August 23 with observations on the number of bees with pollen loads from each of 86 species of plants. Synge (1947) trapped pollen from colonies of honey bees, and analyzed the daily catch into its constituent pollen species to obtain a quantitative estimate of pollen sources. This resulted in dividing the season into four periods: an early spring forest tree flow; a spring rosaceous tree and shrub flow; a summer legume flow; and a fall

composite flower flow. Eckert (1942) said that all colonies do not work on the same source of pollen in a given locality, but that seasonal trends do exist. Percival (1955) gave an excellent report on the blooming period of 86 species of angiosperms. This included the peak hours the pollen was shed, the hours it was collected by honey bees, and the duration of bloom. Oertel (1939) prepared a list of the major honey and pollen plants of the United States and a chart showing the seven-year averages in blooming periods. The chart for Michigan includes: soft maple (April); willow (late April and early May); hard maple (early May); dandelion (May); fruit bloom (May); white and alsike clover (June and July); raspberry (late June through early July); sweet clover (July through August); milkweed (July); basswood (July); buckwheat (August); goldenrod (late August through September); and aster (September through early October).

Percival (1947) listed plants that ranged from major importance to the honey bee to plants that did not attract any bees. She attempted to identify reasons for marked variation in bee visits to different plant species. Percival (1949) analyzed six species of important pollen plants as to their pollen presentation and pollen collection and found white clover (Trifolium repens L.) to be the most preferred pollen. Synge (1947) fed pollen to bees and found white clover was always preferred over red clover, and that bees preferred legumes over most other pollen. Also the bulk of pollen was collected from a few species with clovers (54%), rosaceous trees and shrubs (15%), and forest trees (11%) yielding 80% of the total flow. Oertel (1939) reported corn and oak, principally wind pollinated plants, as important pollen sources.

METHODS

Pollen was trapped at the M.S.U. Apiary for two consecutive years to determine the most important pollen sources in East Lansing. Trapping over two years removed some yearly variations and established a more accurate average flow from each source. During the 1970 season, pollen was trapped from two colonies twice a day for five days a week from April 13 until October 30. In 1971 pollen was collected from two colonies once a week from April 15 until October 21. Once trapped, samples were identified as mentioned in Chapter 1. Data was summarized each week to obtain average values of pollen sources, then the weekly averages were tabulated to find seasonal trends.

RESULTS AND DISCUSSION

Plant Blooming Periods - Calculations resulting from the trapping and identification of pollen yielded weekly and seasonal data on the most important pollen sources. This massive volume of data, 147,989 pollen pellets sorted resulting in 4,520 separate identifications in 1970 and 18,600 pellets sorted in 1971, is summarized in Figure 5. The phenological chart shows concisely the blooming period of the major pollen plants in East Lansing in 1970 and 1971 and their relative importance as pollen sources each week. It also indicates that some species present all their pollen within a week while others may bloom as long as three months.

In April, a few species, *Acer* spp. and *Salix* spp., provided most of the pollen. These were plentiful and supplied copious amounts of pollen in a matter of a few days. With the complex of species present and the demand for pollen so great within the hive, bees

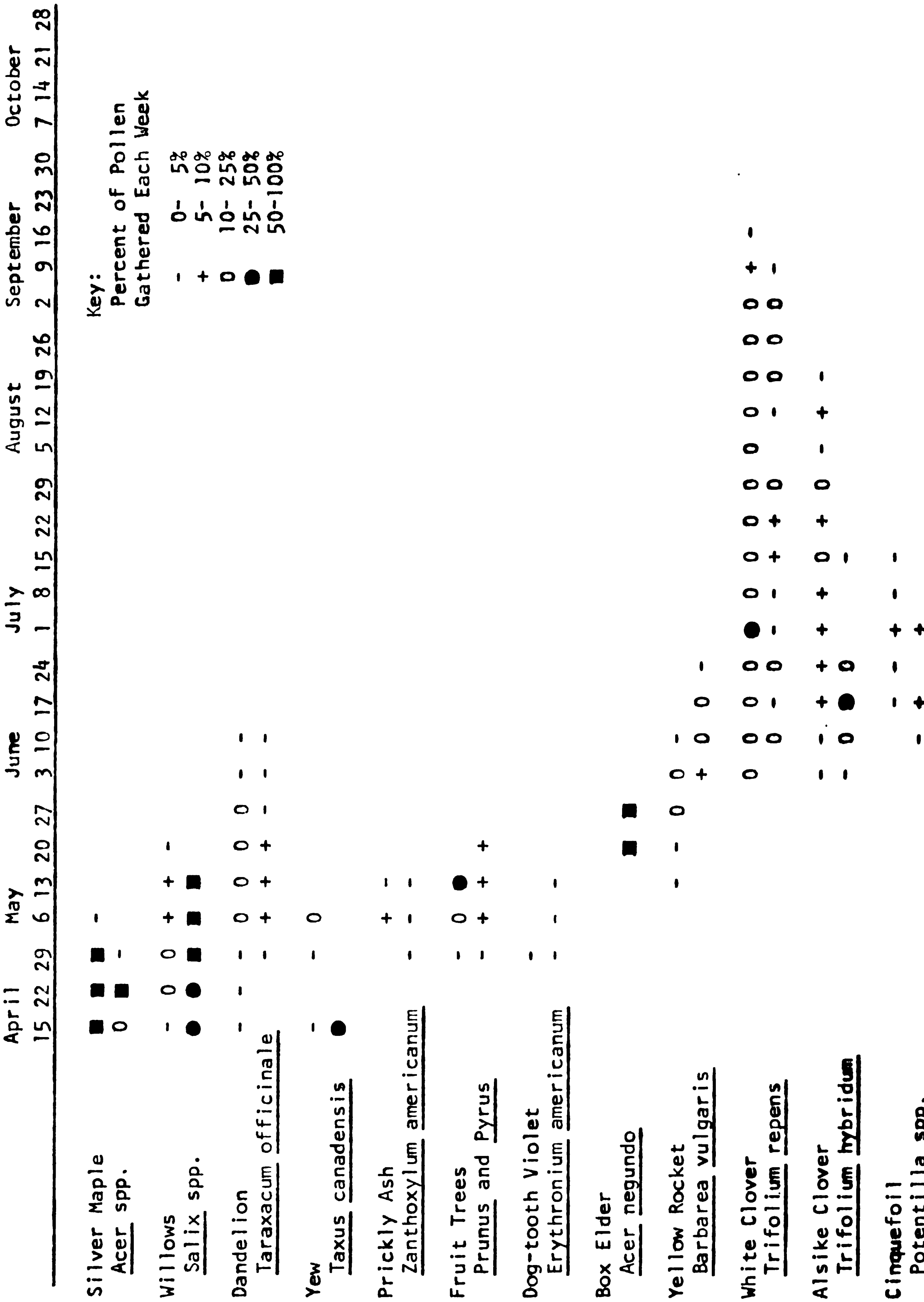

Fig. 5. Calendar of Pollen Plants in East Lansing in 1970 (first row of each species) and 1971 (second row of each species) in Percent of Pollen Gathered Each Week.

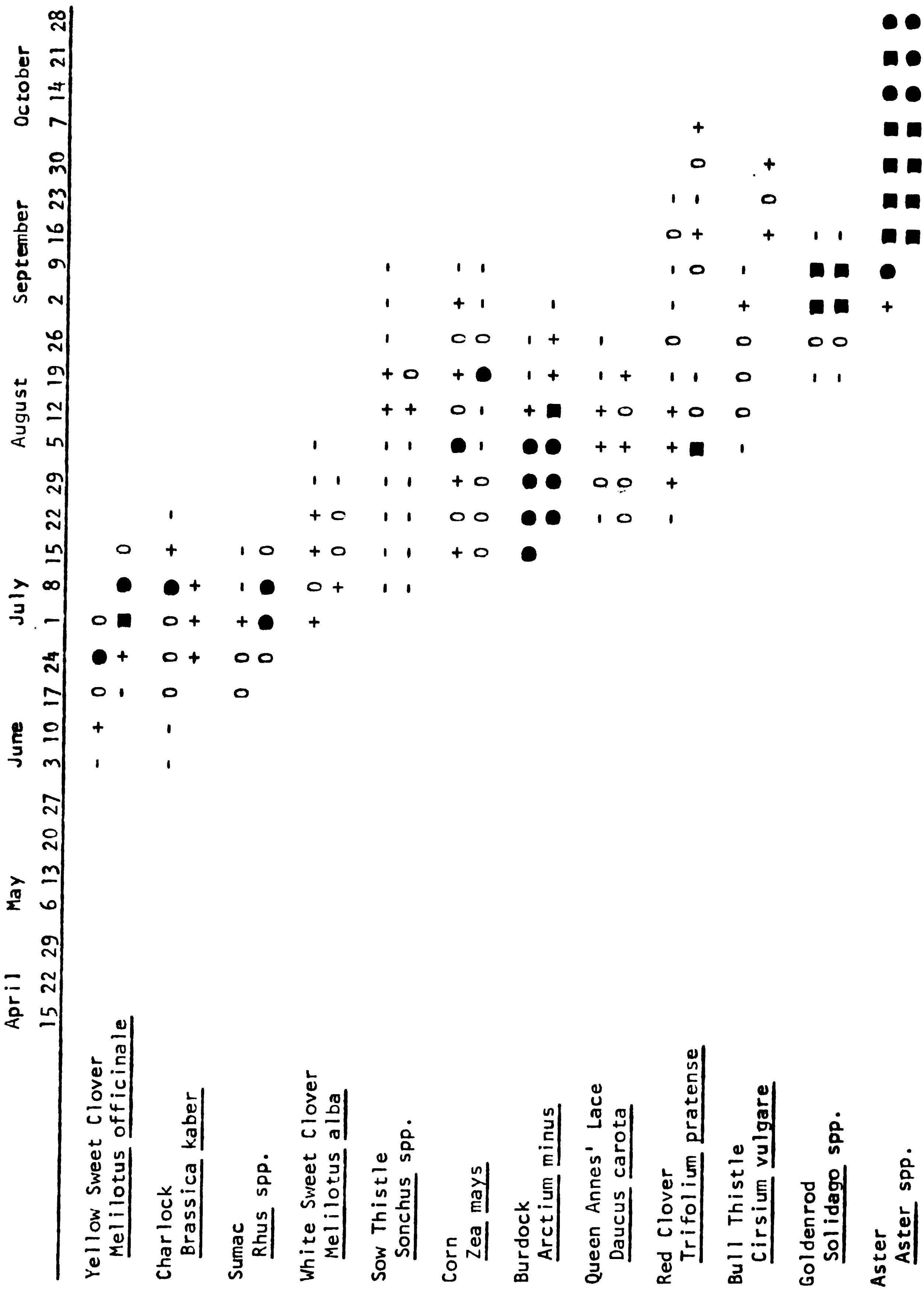

Fig. 5. Continued.

gathered the pollen avidly. These species provided the protein source for the early spring colony buildup.

Through most of May, no single species predominated, but several minor sources were present and worked by bees to some extent. This situation is typical in the East Lansing area, but in other parts of the state, namely the fruit areas, a single species may provide nearly 100% of a week's pollen supply. One species that deserves mention is dandelion (Taraxacum officinale Weber). It was considered one of the most important seasonal pollen sources before this study, but it never produced more than 25% of a weekly sample.

During June and July, the legume family provided most of the pollen. Each year the first week of June, white clover and alsike clover (Trifolium hybridum L.) came into bloom. These two species bloomed for a considerable length of time and provided pollen constantly which resulted in them being very important pollen sources. Yellow sweet clover (Melilotus officinale Desr.) bloomed the first week of June in 1970 and mid-June in 1971 and it provided pollen for five weeks both years with more in 1971. White sweet clover (Melilotus alba Desr.) bloomed just as yellow sweet clover ceased, this being the first and second week of July in 1970 and 1971 respectively. Pollen yield was slightly higher in 1970, due mainly to plants being in bloom approximately two weeks longer. These four legumes are considered excellent nectar sources as well as major pollen sources.

Two members of the mustard family also provided pollen from mid-May until mid-July in 1970 and through June in 1971.

These two species were the cosmopolitan weeds yellow rocket (Barbarea vulgaris R. Br.) and charlock (Brassica kaber Wheeler). Charlock provided significantly more pollen in 1970 than in 1971 due to a five-acre research plot planted one-fourth mile from the apiary.

Four species of plants provided most of the pollen in July and August. Sumac (Rhus spp. L.) provided more pollen than expected both years. It bloomed from mid-June through mid-July and provided up to 29% of one week's pollen supply. Corn (Zea mays L.) was a major pollen source with as much as 33% of the week's supply coming from it. In 1970 three peaks of gathering were observed indicating different fields coming into bloom. Queen Anne's Lace (Daucus carota L.) yielded up to 32% of a week's supply indicating its pollen yielding potential. It bloomed from mid-July to mid-August both years. Burdock (Arctium minus Schk.) bloomed at the same time as Queen Anne's Lace, but provided much more pollen. This weed seemed to be present everywhere, and provided over 50% of the total intake one week and over 25% of the total during one four-week period.

Two groups of fall flowers, with their variety of species, provided practically all the fall pollen. Goldenrod (Solidago spp. L.) bloomed from mid-August through mid-September with the same blooming dates and weekly yields for both years. Aster (Aster spp. L.) bloomed from early September until late October both years. These two species are very important to the colony in providing pollen stores for winter and early spring brood rearing as well as honey for wintering.

Most Important Pollen Plants - Table 2 ranks each species according to the percentage of pollen it supplied to the colony throughout the year. The aster complex that bloomed in late fall and provided pollen stores for overwintering provided most of the pollen. White and alsike clover were second in importance and provided most of the pollen throughout the summer as well as being an excellent nectar source. All of the most important sources have wide distribution and long blooming periods. Other plants of major importance that previously were not considered so are: burdock, the willows, corn, sumac, and Queen Anne's Lace. Table 3 lists all the plants which provided less than one percent of the season's pollen supply. Collectively these plants provided a great diversity of pollen which may be important in providing a continuity of supply and a nutritional balance.

Table 2

Percent of the Total Pollen Flow Each Species Provided From April 15 Until October 31, 1970 and 1971 in East Lansing

Flower		Percent of Total	
Common Name	Scientific Name	1970	1971
Aster	*Aster* spp. L.	9.56	15.50
White clover	*Trifolium repens* L.	10.83	4.62
Burdock	*Arctium minus* Schk.	4.59	6.69
Goldenrod	*Solidago* spp. L.	4.68	5.90
Corn	*Zea mays* L.	5.52	3.69
Unknown	Cichorieae	4.29	5.09
Yellow Sweet clover	*Melilotus officinalis* Desr.	3.75	5.38
Charlock	*Brassica kaber* Wheeler.	3.75	.79
Maple	*Acer* spp. L.	4.20	2.38
Alsike clover	*Trifolium hybridum* L.	3.44	2.70
Bull thistle	*Cirsium vulgare* Tenore.	3.40	1.61
Sumac	*Rhus* spp. L.	2.00	3.29
Red clover	*Trifolium pratense* L.	1.81	4.62
Queen Anne's lace	*Daucus carota* L.	1.79	2.37
Dandelion	*Taraxacum officinale* Weber.	2.36	1.02
Yellow rocket	*Barbarea vulgaris* R. Br.	1.40	2.10
Sow thistle	*Sonchus* spp L.	1.41	1.08
White Sweet clover	*Melilotus alba* Desr.	1.52	.71
Willow	*Salix* spp. L.	.90	8.81

Table 3

Plant Species that Provided Less Than One Percent of the Seasons Pollen Flow in East Lansing in 1970 and 1971

Common Name	Scientific Name
Alfalfa	Medicago sativa L.
Bird's foot trefoil	Lotus corniculatus L.
Black cherry	Prunus serotina Ehrh.
Bloodroot	Sanguinaria canadensis L.
Boxelder	Acer negundo L.
Canada thistle	Cirsium arvense Scop.
Chicory	Cichorium intybus L.
Cinquefoil	Potentilla spp. L.
Dog-tooth violet	Erythronium americanum Ker.
Elderberry	Sambuscus pubens Michx.
Fruit trees	Prunus and Pyrus spp. L.
Grape-hyacinth	Muscari botryoides (L.) Mill.
Gray dogwood	Cornus racemosa Lam.
Motherwort	Leonurus cardiaca L.
Mustard	Brassica spp. L.
Poison ivy	Rhus radicans L.
Prickly ash	Zanthoxylum americanum Mill.
Ragweed	Ambrosia artemisiifolia L.
Smartweed	Polygonum spp. L.
Spirea	Spiraea alba DuRoi.
Sweet alyssum	Berteroa incana (L.) DC.
Teasel	Dipsacus sylvestris Huds.
Touch-me-not	Impatiens spp. L.
Yew	Taxus canadensis Marsh.

CHAPTER 3

THE COLLECTION OF POLLEN BY COLONIES OF TWO RACES

INTRODUCTION

To supplement information on plant sources of pollen, the periodicity of pollen flows and amounts of pollen collected, the pollen-gathering characteristics of two races of bees were compared. It was assumed that no differences existed between the race relative to pollen collection, and that there was greater variability within each race than between the races. To test this hypothesis, queens of predominantly Italian and Carniolan ancestry were introduced into similar colonies. Pollen was trapped after their progeny were field bees and identified as usual, and differences tested by the paired-t test.

LITERATURE

Honey bee races have been compared relative to their ability to collect pollens under various environmental conditions. Wilson (1963) reported Caucasian bees seemed to work under more adverse conditions than Italians, and Italians are not as active on cool, cloudy days. Warakomska and Louveaux (1964) compared the collection of pollen by colonies of different races. Using five colonies of each race they found that one race gathered significantly more pollen and also visited more plant species, with the other race gathering most of its pollen from a few species. Louveaux (1959) compared groups of bees of different geographical origin as to the type of pollen collected and found that there was greater variability within the homogeneous groups than between the groups. Maurizio (1953) noted that colonies in the same apiary differed in the amount and origin of pollen collected, though the principal sources of forage available were less subject to variation. The ultimate in the comparison of strains of bees is the development of bees for pollination of specific crops. Marucci (1967) said some strains collected cranberry pollen more avidly than others. Mackensen and Nye (1969) selected a strain for alfalfa pollen collection and demonstrated that alfalfa pollen preference was a genetic characteristic of the strain and that the trait was heritable.

METHODS

On April 29, 1970 five queens each of Carniolan and Italian races were introduced into colonies at the MSU Apiary. These queens were obtained from Dr. William Roberts at the USDA Bee Stock Center at Baton Rouge, Louisiana, and were three-way hybrid crosses. The Italian dominant strain was (Pa x Pb) x YD and the Carniolan dominant line was (KG x Kc) x Ro. Six weeks elapsed after requeening before the experiment was initiated; this time period allowed all foragers to be progeny of the hybrid queens. O.A.C. pollen traps were placed in position during this time to take continuous pollen samples. The samples collected were identified by standard procedures mentioned in Chapter 1, and beginning June 7 were compared for racial differences. One colony of each race was trapped each morning and each afternoon five days a week resulting in 20 samples per week. The trapping sequence is shown in Table 4. A Carniolan colony became queenless the last week of July, and the remainder of the season only nine colonies were used. On October 1 the sampling procedure was simplified by using the strongest colony of each race, still collecting samples twice daily. This continued until October 31 at which time no more pollen appeared in the traps.

Table 4

Time Schedule for Trapping Pollen from Different Races of Bees at East Lansing, Michigan in 1970

Time (EST)	Race	Mon.	Tue.	Wed.	Thur.	Fri.
Morning	Italian	2*	11	24	3	14
Sunrise - 1 p.m.	Carniolan	10	7	26	15	12
Afternoon	Italian	3	14	2	11	24
1 p.m. - Sunset	Carniolan	15	12	10	17	26

*Numbers in Table refer to a specific colony.

RESULTS AND DISCUSSION

Pollen Gathering by the Italian Colonies - White clover was found to yield pollen the longest (17 weeks) for the Italian colonies. Other durations of bloom included alsike clover yielding for 11 weeks, sow thistle and aster for 9 weeks, white sweet clover and Queen Anne's Lace for 7 weeks, and yellow sweet clover, charlock and burdock for

6 weeks. Corn showed three peaks of flow indicating different fields coming into bloom. By totaling the number of pellets gathered from each species for each week, the relative importance can be found for the total sampling period of June 7 through October 31. Table 5 lists each plant species according to its percentage for the 21-week period. Two plants, aster and white clover provided most of the season's pollen supply yielding 11.97 and 11.96 percent respectively. Three other plants, burdock, goldenrod and corn provided between 5-10% of the sample, and are considered major pollen plants. Several plants provided 1-5% of the season's total, and were considered minor pollen plants for the area in 1970. Some of the more common of these were: charlock, yellow sweet clover, and alsike clover.

<u>Pollen Gathering by the Carniolan Colonies</u> - White clover pollen appeared in the traps on the Carniolan colonies for 18 weeks; with alsike clover and sow thistle presenting pollen for 10 weeks; aster for 9 weeks; charlock, white sweet clover and burdock for 7 weeks; and yellow sweet clover for 6 weeks. White clover and aster provided most of the pollen (Table 5) yielding 15.93 and 14.16 percent respectively. Other important pollen plants that provided between 5-10 percent of the total were: burdock, bull thistle, and charlock. Besides these there were 10 other plant species representing 1-5 percent of the season's flow, with the most common plants being yellow sweet clover, alsike clover, goldenrod, and corn.

<u>Differences Between the Races in Pollen Gathering</u> - Table 5 lists the plant species and the percentage of pollen throughout the season. These numbers were obtained by adding the actual number of pellets

Table 5

Percent of Different Pollens Gathered by Two Races of Bees
From June 7 Until October 31 at East Lansing in 1970

Flower Common Name	Scientific Name	Italian	Carniolan
White clover	Trifolium repens L.	11.96	15.93*
Aster	Aster spp. L.	11.97	14.16*
Burdock	Arctium minus Schk.	7.14	8.45
Goldenrod	Solidago spp. L.	7.65	4.50
Corn	Zea mays L.	8.50**	3.17
Unknown	Cichoreae	5.25	5.63
Charlock	Brassica kaber Wheeler.	4.06	6.05
Yellow Sweet clover	Melilotus officinale Desr.	5.11	4.77
Bull thistle	Cirsium vulgare Tenore.	2.41	7.26
Alsike clover	Trifolium hybridum L.	4.28	4.77
Sumac	Rhus spp. L.	3.02	2.36
Queen Anne's lace	Daucus carota L.	2.94*	1.84
White Sweet clover	Melilotus alba Desr.	2.38	1.70
Red clover	Trifolium pratense L.	3.54*	.52
Sow thistle	Sonchus spp. L.	1.10	2.43**
Touch-me-not	Impatiens spp. L.	1.39	.79
Ragweed	Ambrosia artemisiifolia L.	1.57*	.11
Canada thistle	Cirsium arvense (L.) Scop.	.38	1.17
Other		15.35	14.39

*Indicates significantly different at the 5% level by the paired-t test.

**Indicates significantly different at the 1% level by the paired-t test.

that each plant provided each week, and finding a seasonal percentage based on the total number of pellets identified for the season.

Pollen collection by the two races was very similar; however, by the paired-t test, certain nonchance differences do exist. The Italian race gathered significantly more pollen from Queen Anne's Lace, red clover, and ragweed; and significantly less pollen from white clover, aster, and bull thistle than the Carniolan race at the 5 percent level of confidence. At the 1 percent probability level the Italians gathered significantly more from corn and significantly less from sow thistle. This test indicates that these differences will only occur by chance 1 percent of the time, therefore, reasons exist for these great differences. A plausible explanation was found during the week of August 23-29 for corn pollen. Throughout the week nine colonies ranged from 1 to 17 percent corn pollen in the samples; however, one colony (#3, Italian) concentrated on corn and collected over 50 percent of its pollen from it. This is an exception, and can be used to indicate the variability in corn pollen collection, however, all of the other colonies for all of the significantly different plants gathered approximately the same amount from each plant for each week. Another explanation may be that Carniolans tend to fly more in adverse weather which might alter pollen collecting patterns. It is also conceivable that variability in pollen collecting may be due to genetic preferences of the bee.

CHAPTER 4

MORNING AND AFTERNOON POLLEN GATHERING

INTRODUCTION

This study was concerned with the time of day bees gather pollen from specific plants. Pollen was trapped in the morning and in the afternoon, and identified as to source. It was assumed that certain plants would present their pollen in the morning, others in the afternoon, and some all day. Reasons for carrying out this project were to determine diurnal patterns of pollen presentation, and by doing so to elucidate recommendations as to best times to apply pesticides to reduce bee losses.

LITERATURE

Many workers who have studied bee-gathered pollen have reported that pollen was collected from different species of plants at different times of the day, (Maurizio, 1953; Parker, 1926; Shaw, et. al., 1954). In addition, Pritsch (1962) reported that more plants yielded pollen in the morning than in the afternoon or plants that yielded all day. Pollen yielding characteristics of some plants have been studied in detail. Cirnu (1964) studied corn, and reported that it was attractive to bees, especially when little other pollen was available. Bees visited it eagerly in the morning and at noon, and visited 8-10 flowers to get a pollen load. Parker (1926) listed corn and ragweed as plants shedding pollen in the morning and sweet clovers and white clover as yielding all day. Free (1970) studied pollen gathering in apples and noted that a higher percentage of apple pollen was found in afternoon samples. Percival (1947) said pollen collection takes place throughout the day if weather conditions permit, however, certain plants present their pollen for only a few hours during the day. Time of day differences were due to proximity of the crop, time of day of pollen presentation, or competition between species. Percival (1949) followed the pollen presentation and pollen collection of several plants, and reported that *Trifolium repens* collection time lagged about one hour behind its presentation time. Vansell and Todd (1948) noted that some plants, such as chicory, greasewood, morning glory, some tarweeds, and wild lettuce, shed pollen only during a short period of the day, whereas some of the most important plants present pollen throughout the day.

METHODS

Pollen was trapped from honey bee colonies from April 13 through October 31, 1970 at East Lansing, Michigan. Trapped pollen was collected from two colonies each morning (sunrise until 1:00 p.m. EST) and each afternoon (1:00 p.m. until sundown) Monday through Friday each week. Once identified, weekly averages were found for each species, and differences tested by the paired-t test.

RESULTS AND DISCUSSION

Pollen Gathering in the Morning - Table 6 shows the most important plants from which pollen was gathered both in the morning and in the afternoon. White clover was the most important morning source. Three other plants, corn, aster, and charlock, were major morning sources and provided between 5-10% of the sample. A host of other plants provided less

Table 6

Percent of Pollen Gathered in the Morning[1] and Afternoon[2] at East Lansing in 1970

Flower Common Name	Scientific Name	Morning	Afternoon
White clover	*Trifolium repens* L.	10.77	10.87
Aster	*Aster* spp. L.	5.99	13.11**
Burdock	*Arctium minus* Schk.	4.56	4.83*
Goldenrod	*Solidago spp*. L.	4.33	4.98
Unknown	Cichorieae	6.38***	2.07
Corn	*Zea mays* L.	6.12*	2.32
Maple	*Acer saccharinum* L.	3.97	4.37
Charlock	*Brassica kaber* Wheeler.	5.80*	1.91
Yellow Sweet clover	*Melilotus officinale* (L.) Desr.	2.82	4.65*
Alsike clover	*Trifolium hybridum* L.	3.72	3.10
Bull thistle	*Cirsium vulgare* Tenore.	2.67	4.10*
Dandelion	*Taraxacum officinale* Weber.	2.36	2.34
Crab apple	*Pyrus* spp. L.	2.07	2.46
Sumac	*Rhus* spp. L.	2.52	1.43
Sow thistle	*Sonchus* spp. L.	2.47**	.30
Red clover	*Trifolium pratense* L.	1.32	2.29**
Queen Anne's lace	*Daucus carota* L.	2.29*	1.24
White Sweet clover	*Melilotus alba* Desr.	1.44	1.58
Yellow rocket	*Barbarea vulgaris* R. Br.	1.77	1.00
Ragweed	*Ambrosia artemisiifolia* L.	1.10*	.14

[1] First flight to 1:00 p.m. EST.

[2] 1:00 p.m. EST to end of flight.

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*Significantly different at the 5% level.

**Significantly different at the 1% level.

***Significantly different at the .1% level.

than 5 percent of the seasonal sample, and some of the more common of these are: burdock, goldenrod, maple, and alsike clover.

Pollen Gathering in the Afternoon - Table 6 shows the relative importance of each species as a percentage of the total seasonal flow. Aster and white clover provided most of the pollen. There were no plants in the major category of 5-10% of the flow. The more common minor sources included: goldenrod, burdock, yellow sweet clover, maple and bull thistle.

Differences Between Morning and Afternoon Pollen Gathering - The paired-t test was run on the data in Table 6, and significance noted between the morning and afternoon pollen sources. In this test #184 (Cichoreae), sow thistle, corn, charlock, Queen Anne's Lace, and ragweed pollens were gathered significantly more in the morning. Aster, burdock, yellow sweet clover, bull thistle, and red clover were gathered significantly more in the afternoon. Dandelion, alsike clover, white clover, and goldenrod pollens were gathered throughout the day, with approximately equal amounts being collected mornings and afternoons. This disputes reports (Free, 1970) that dandelion is a morning blooming species and goldenrod an afternoon blooming species, and confirms reports (Parker, 1926) that white clover blooms all day and corn and ragweed present pollen in the morning. Greater gathering from aster in the afternoon may be explained by the fact that it blooms in late fall when morning temperatures are too cool for bee flight.

CHAPTER 5

COMPARISON OF POLLEN GATHERING PATTERNS IN FOUR DIFFERENT LOCATIONS IN SOUTHERN MICHIGAN IN 1971

INTRODUCTION

Colonies of bees were located at five different sites in southern Michigan. From these sites, a calendar of plant blooming dates was prepared, along with pollen flow records. This data indicates which plants were the major pollen sources at different locations in the state.

LITERATURE

Comparisons of pollen collection in different locations have been carried out by several workers to obtain a clearer picture of pollen availability and honey bee preferences. Vansell and Todd (1948) trapped pollen from 39 localities in Western United States. The results indicated the relative value to bees of plant species in each locality. Brown (1967) trapped pollen at three locations in Louisiana, identified it, and classified the major pollen sources of spring, summer and fall. His work reconfirmed that adjacent colonies differed in pollens collected. Maurizo (1953) trapped pollen from four localities in Switzerland and reported that in all districts only a few plant species provided the bulk of the pollen. Numerous other species provided a small proportion of the whole and were quite variable in that amount. Riedel and Wilson (1967) trapped pollen at four altitudes in the mountains of Colorado to determine which plants were sources of pollen for bees and whether sufficient pollen was available in the mountains for minimum brood rearing. Svendsen (1964) trapped pollen at four localities in northern Zealand with different forage conditions. He found that white and red clover, mustard, and cornflower pollen was collected in each location. White clover was the major source for at least one colony at each location, but in general (and especially for red clover) the pollen yield was roughly inversely proportional to the distance from the crop. Louveaux (1956) assembled pollen collection data at three different geographical regions and found bees began gathering pollen earlier in the season in the southern region than in the northern region. Louveaux (1963) reported that colonies left in one location gathered a wide variety of pollens whereas colonies that were moved to a new location collected pollen from a comparatively few species and different colonies gave remarkably similar results.

METHODS

The help of 4-H and FFA members was solicited to aid with the collection of data. Four locations surrounding Lansing were selected to study the geographical distribution of pollen gathering. At each of these locations pollen traps were placed on hives. Every third week I returned to each of these locations to retrieve the trapped pollen, survey the flowering plants, and inspect the colonies.

Mr. Michael Connor, a 4-H student, carried out routine trapping at a location two miles north of Galesburg in Kalamazoo County. Four colonies of bees from the MSU Apiary were used.

Pollen traps were placed on the two strongest hives, and Mr. Connor removed the pollen each Tuesday from April 15 until September 9 and kept it in a freezer to preserve it. In mid-season, the traps were switched to the other two colonies which were stronger. This area contained mostly swamp and open fields with a few fruit trees and a small agricultural area of corn with a sandy soil predominating.

Mr. Joe Howard, an active 4-H leader in beekeeping, trapped pollen from two colonies located in his apiary near Belleville in Wayne County. He removed the pollen each Wednesday from April 22 through September 30 and stored it by freezing. The area around his apiary was mainly open fields and excellent for foraging.

Mr. Eugene Montague, a 4-H student, trapped pollen from two colonies in his apiary just north of Ovid in Clinton County. Pollen was collected each Thursday from April 22 until September 9. Midway through the season the traps were placed on two stronger colonies. The flora in the locality was highly agricultural with 15 acres of apples adjacent to the bees, and many acres of corn and soybeans in neighboring fields.

Ionia is located approximately 40 miles northwest of Lansing. There an FFA member, Ron Blondi, placed two pollen traps on colonies in his apiary, and gathered samples every Friday. The surrounding area was approximately 80 percent corn plantings and appeared to have limited flora for good bee forage. Within one month, all the hives developed foulbrood and were burned, and available data from this area was not used.

RESULTS AND DISCUSSION

East Lansing

Seasonal Calendar of Pollen Plants - Pollen was collected each Monday from mid-April to October 21 in 1971 from two colonies at the MSU Apiary, and results are indicated in Fig. 5, page 14. This shows when the major plant species bloomed and the relative amount of pollen gathered from each species. Discussion of this data is found on pages 13 through 17.

Most Important Pollen Plants - In 1971, aster provided the highest percentage of pollen in East Lansing (Table 7). Other plants that were of major importance included: willows, burdock, goldenrod, and yellow sweet clover. These plants dominated the local flora, and apparently provided the quantity and variety of pollen necessary to support brood rearing and adult nutritional requirements necessary to build strong colonies.

Galesburg

Seasonal Calendar of Pollen Plants - Fig. 6 shows the blooming period of plants in Galesburg and the relative importance of each species. Maple and willow dominated the spring sources with dandelion and spring beauty (*Claytonia virginica* L.) supplying the rest. Traps from the week of May 20 contained mainly apple (*Pyrus malus* L.) pollen because there was an orchard in bloom adjacent to the hives. Just as apples ceased to bloom, the legumes started and dominated the summer flows with the sweet clovers providing most of the pollen. Other plants such as sumac, star-thistle (*Centaurea maculosa* Lam.), and elderberry (*Sambucus pubens* Michx.) provided small amounts. The

TABLE 7

Percent of Pollen Gathered at Four Sites in Southern Michigan in 1971

Plant		Location			
Common Name	Scientific Name	East Lansing	Gales-burg	Belle-ville	Ovid
Aster	Aster spp. L.	15.50	1.95	1.03*	1.65*
Goldenrod	Solidago spp. L.	5.90	7.84	8.38	9.79
Burdock	Arctium minus Schk.	6.69	1.21	0.00	4.29
White clover	Trifolium repens L.	4.62	.26	5.30	.85
Yellow Sweet clover White Sweet clover	Melilotus officinale Desr. Melilotus alba Desr.	6.09	11.68	12.46	4.74
Corn	Zea mays L.	3.69	2.44	1.61	16.93
Charlock	Brassica kaber Wheeler	.79	0.00	3.08	.48
Yellow rocket	Barbarea vulgaris R. Br.	0.00	4.86	4.06	3.34
Bull thistle Canada thistle	Circium vulgare Tenore Circium arvense Scop.	1.61	0.00	0.00	.14
Alsike clover	Trifolium hybridum L.	2.70	2.26	.61	.54
Sumac	Rhus spp. L.	3.29	3.83	.56	0.00
Queen Anne's lace	Daucus carota L.	2.37	1.46	.32	.43
Red clover	Trifolium pratense L.	4.62	3.38	0.00	2.45
Sow thistle	Sonchus spp. L.	1.08	.01	2.62	3.08
Touch-me-not	Impatiens spp. L.	.15	0.00	0.00	0.00
Ragweed	Ambrosia artemsiifolia L.	.12	0.00	0.00	2.41
Maple	Acer spp. L.	2.38	16.26	5.47	.55
Willow	Salix spp. L.	8.81	2.95	3.58	6.92
Dandelion	Taraxacum officinale Weber	1.02	2.29	1.47	2.52
Fruit trees	Pyrus and Prunus spp. L.	0.00	3.23	0.00	15.48
Chicory	Cichorium intybus L.	0.00	0.00	.33	3.14
Star thistle	Centaurea maculosa Lam.	0.00	3.10	0.00	0.00
Elderberry	Sambucus pubens Michx.	0.00	1.78	0.00	0.00
Purple loosestrife	Lythrum salicaria L.	0.00	3.83	0.00	0.00
Cinquefoil	Potentilla spp. L.	0.00	0.00	1.54	0.00
Smartweed	Polygonum spp. L.	0.00	0.00	17.92	0.00
Others		28.57	25.38	29.66	20.27

*Pollen traps were removed before this species achieved full bloom.

	April			May				June				July				August				
	15	22	29	6	13	20	27	3	10	17	24	1	8	15	22	29	5	12	19	26	2
Maple	■	■	■	■	■																
Willow	-	0	●	-	-	-															
Dandelion			-	0	0	+		-	-												
Spring Beauty			-	0	-																
Apple					+	■															
Yellow Rocket						0	●	●	+												
Gray Dogwood							+	●	+	0	-	-									
White Clover							-		-	-	-										
Alsike Clover							-	+	0	●	-	-									
Sweet Clovers										●	■	-				●	●	0	●	●	0
Sumac										-	-	■									
Star Thistle													+	0	●			-			
Elderberry													0	+	+	-					
Plantain														-	0	-	-	-			
Corn														+		-	0	0			
Purple Loosestrife															+	0	●	0	-	-	
Red Clover															0	+	0	0	+	+	-
Queen Anne's Lace																0		+			
Burdock																-	-	+	-	+	
Ragweed																	-		+	-	
Goldenrod																	-	+	●	●	■

Percent of Pollen Gathered Each Week

-	0- 5%
+	5- 10%
0	10- 25%
●	25- 50%
■	50-100%

Fig. 6. Calendar of Pollen Plants in Galesburg Michigan in 1971.

late summer and early fall species that provided significant amounts of pollen were plantain (Plantago spp. L.), corn, purple loosestrife (Lythrum salicaria L.), red clover, Queen Anne's lace, burdock and ragweed. The late fall flowers were missed because the traps were removed too early, but a significant amount of goldenrod pollen was gathered.

Most Important Pollen Plants - Table 7 lists the percentage of pollen each of the most common plants provided throughout the season. Maple provided the most and was a very important species in this location. Other major plants included the sweet clovers and goldenrod. Star-thistle and purple loosestrife provided much pollen at this location but were lacking at other sites. Aster, even though in the sample only once, was a minor source and likely would have been the most important source if traps had been left in position later in the season.

Belleville

Seasonal Calendar of Pollen Plants - Fig. 7 shows the blooming period for plants near Belleville and their relative importance as pollen sources each week. The spring blooming trees, maple and willow, provided most of the pollen early in the season. Commencing in May a variety of species including dandelion and yellow rocket provided most of the pollen. Through June and July clovers dominated the pollen flow. Other plants that provided some pollen included: charlock, cinquefoil and gray dogwood. In August, pollen was gathered from chicory, smarteed, corn, sow thistle, cucumber (Cucumis sativus L.), ragweed, and goldenrod. Asters began bloom in mid-September but traps were removed before they reached full bloom.

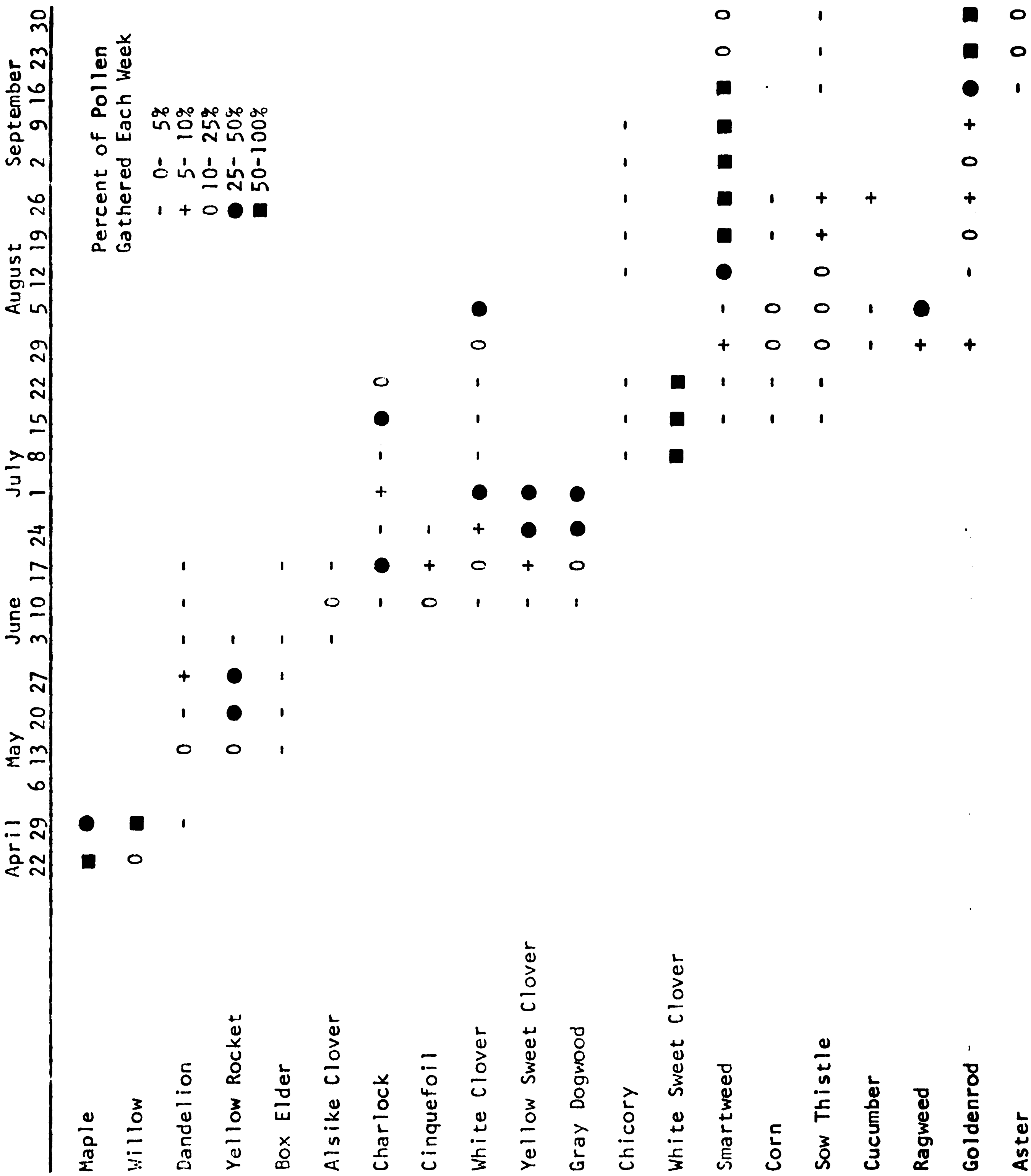

Fig. 7. Calendar of Pollen Plants in Belleville Michigan in 1971.

Most Important Pollen Plants - Table 7 lists each plant and the percentage of pollen it provided for the season at Belleville. Smartweed provided the greatest amount of pollen in this area. In other areas of the state, this is a very minor source, but in this locality it was a very prevalent plant in the roadside ditches and fencerows. Other plants of importance to this area included goldenrod, clovers and maple. More pollen probably would have been gathered from aster if the traps had been left in place longer.

Ovid

Seasonal Calendar of Pollen Plants - Fig. 8 shows the sequence of bloom of pollen plants in the Ovid area. Maple pollen was in the traps one week, but considerably more pollen would have been gathered from it if the traps had been in place sooner. Willow provided much pollen and was the major spring source, and others were trillium (*Trillium* spp. L.) and yellow rocket. These colonies were adjacent to an apple orchard and only limited amounts of other pollen was collected during this period. Clovers provided much of the summer pollen from early June through mid-August. A few crops grown in the area also provided some pollen. Corn was the major source for three weeks and bees worked a small field of buckwheat (*Fagopyrum esculentum* Moench) and gathered pollen from it. The common weeds chicory, burdock, Queen Anne's lace, sow thistle, and ragweed also provided some pollen through August. The fall blooming plants goldenrod and aster provided pollen late in the season, and more pollen would have been gathered from aster if the traps would have remained on the colonies longer.

	April		May				June				July					August				Sept.	
	22	29	6	13	20	27	3	10	17	24	1	8	15	22	29	5	12	19	26	2	9
Maple	0																				
Willow	●	●	●	-	-																
Yellow Rocket				-	+	0	0	-													
Tree Fruits			0	●	■	■	■	■													
Dandelion			-	+	0	+	+	-													
White Clover								+	0	-	-										
Yellow Sweet Clover											■	0									
Corn														■	■	■	0	0	+	+	
Chicory														-	0	+	-	+	+		
Burdock														+	+	0	●	-			
Queen Anne's Lace														-	-						
Sow Thistle														-	-	-	0	0	+	+	
Red Clover																-	0	+	-	+	
Ragweed																		-	0	●	-
Goldenrod																		●	●	■	■

Percent of Pollen Gathered Each Week

- \- 0- 5%
- \+ 5- 10%
- 0 10- 25%
- ● 25- 50%
- ■ 50-100%

Fig. 8. Calendar of Pollen Plants in Ovid Michigan in 1971.

<u>Most Important Pollen Plants</u> - Table 7 lists the percentage of pollen from each source for the entire season near Ovid. Corn and fruit blooms were major sources and together provided one-third of the total season's pollen. Willow was a very important spring source and goldenrod was an important fall source. More pollen would have been gathered from maple if the traps had been in position earlier and more would have been gathered from aster if they had remained on the colonies longer in the fall.

<u>Southern Michigan Pollen Plants</u> - Table 8 summarizes the average percentage each plant species provided for the entire season for four locations in southern Michigan. From this data the most important pollen flows were from the sweet clovers in southern Michigan. Goldenrod was next in importance but would have been more so if the traps would have been in place longer. Tree fruit pollen value was high in this study because two locations were adjacent to apple orchards. Other plants that provided more pollen than was expected included: corn, burdock, red clover, and Queen Anne's lace. The 15 plants listed provided two-thirds of all pollen gathered at the four locations. Several plants were important sources at one or more locations but of lesser total importance than those listed.

Table 8

Average Percent of Different Pollens Gathered From Four Sites in Southern Michigan in 1971

Flower Common Name	Scientific Name	Average Percent
Sweet clovers	*Melilotus* spp. Desr.	8.74
Goldenrod	*Solidago* spp. L.	7.98
Corn	*Zea mays* L.	6.17
Maple	*Acer* spp. L.	6.16
Willow	*Salix* spp. L.	5.56
Aster	*Aster* spp. L.	5.03
Fruit	*Prunus* and *Pyrus* spp. L.	4.68
Yellow rocket	*Barbarea vulgaris* R. Br.	3.06
Burdock	*Arctium minus* Schk.	3.05
White, Red, Alsike clover	*Trifolium* spp. L.	2.30
Sumac	*Rhus* spp. L.	1.92
Dandelion	*Taraxacum officinale* Weber.	1.82
Sow thistle	*Sonchus* spp. L.	1.70
Queen Anne's lace	*Daucus carota* L.	1.14
Others		40.69

CHAPTER 6

PLANTS WHICH COMPETE FOR BEE VISITS TO POLLINATED CROPS

INTRODUCTION

Beekeepers rent colonies of bees to growers of bee pollinated crops to insure adequate pollination. One factor of pollination, competitive plants, was studied briefly. Certain plants in the vicinity of the crop can be more attractive to bees than the crop either because of more and higher sugar concentration in the nectar or more attractive or easier to collect pollen. As a result, many bees will forage them rather than the target crop. This study determined which of these plants were competing for pollen-collecting bee activity with apples, blueberries, strawberries, and cucumbers.

LITERATURE

The problem of plants competitive for bee visits to pollinated crops has been reported in the literature for several crops. Dorr and Martin (1966) said attractiveness relative to other plants or other blueberry varieties in the area may be an important factor affecting blueberry yield in Michigan. Collison and Martin (1970) listed 24 plants that were very attractive to bees for nectar or pollen and 12 less attractive plants which competed for bee visits to cucumbers in Michigan. Kremer (1949) reported that several other pollens were collected in traps set out in orchards to accumulate apple pollen. Johansen (1955) reported that bees in Lodi variety of apples collected no apple pollen, but obtained pollen from balsam-root (Balsamorhiza sagittata L.) on a distant hill. These same hives were later moved to Rome Beauty variety and only pure apple pollen was collected until 10:30 a.m. on the third day. As new flight patterns were established, mustard (Brassica campestris L.) and dandelion (Taraxacum officinale Weber) began competing for bee visits. Chambers (1946) reported on pollen loads of Andrena (Hymenoptera, Andrenidae) that visited fruit trees during the bloom period for three years. Hare and Vansell (1946) used pollen traps to determine the sources of bee gathered pollen collected in the large Delta alfalfa seed tract in Utah. Alfalfa pollen composed about 32 percent of the pollen collected from July 31 to August 21, 1944.

METHODS AND LOCATION OF FIELDS

Colonies of bees were located in certain crops during their bloom period in 1971. The number of fields and their location are discussed below. O.A.C. pollen traps were placed on these colonies, and the pollen samples were weighed, a subsample sorted to color, and identified.

Apples - Three commercial apple orchards were used in this study. Two colonies with traps were located within 100 yards of eight acres of Delicious, McIntosh and Jonathon varieties on the farm of Mr. Ernest Connor near Galesburg, Michigan. Traps remained on the hives during the bloom period, May 14-20, 1971.

Two colonies with traps were located on the edge of a 15-acre orchard of mixed varieties on the Raymond Montague farm north of Ovid, Michigan. Traps remained on the hives during the bloom period of May 21-28, 1971.

Two colonies with traps were located in the center of a 100-acre orchard on the Sam Bull farm west of Bailey, Michigan. Traps remained on the hives for eight days, May 20-28, 1971.

Blueberries - Honey bee colonies were placed in a 10-acre field of mixed varieties of highbush blueberries at the Donald Yoder farm near Grand Junction, Michigan. One representative sample of pollen was obtained using the O.A.C. pollen trap.

Strawberries - Front entrance pollen traps were placed on bee colonies in commercial strawberry fields at two locations. Pollen was collected from an 80-acre field of mixed varieties with Midway 1, Midway 2, and Redchief predominating on the Calvin Lutz farm near Kaleva, Michigan. Samples were collected from 8:00 a.m. to 12:00 p.m. and 12:00 p.m. to 4:00 p.m. in three locations within the field on each of two days, May 28 and June 3, 1971. Multiple trapping occurred at each site.

Three samples were taken from a 30-acre field of Redchief variety on the Stanley Radewald farm near Niles, Michigan. Samples were taken for a one-hour period, 3:30 to 4:30 p.m., on June 1, 1971.

Cucumbers - On August 13 six colonies were equipped with O.A.C. pollen traps on the farm of Scott Kiefer near Mulliken, Michigan. Two colonies were placed on the edge of each of three fields, and after field one finished bloom, the colonies were moved to field four. Field one contained 15 acres of cucumbers and was in full bloom at the time. Field two had 10 acres and the first flowers were just opening. Field three had 20 acres and was also just coming into bloom. Field four contained 25 acres and was in one-fourth floom. Pollen was removed from field one on August 19, field two on August 20, field three on August 24 and field four on September 1 (traps on since August 19).

RESULTS AND DISCUSSION

Plants Competitive to Apple Pollination - Results varied considerably between different orchards as expected because of the different vegetation surrounding each orchard. All three orchards had very few weeds or other competitive plants in bloom within their boundaries. Table 9 shows the percentage of each pollen gathered in each orchard.

Orchard number one was surrounded by pine plantations and non-agricultural land. Pollen intake from the target crop average 60.5 percent. This was better than expected because the colonies were in place and flight patterns were established prior to the appearance of apple flowers. Competitive plants in this area included yellow rocket, dandelion, willow, and pine (*Pinus* spp. L.). Few studies have reported pine pollen gathering by bees, but because of its availability and need, it was gathered at this location.

Orchard number two had a larger acreage of apples, and was surrounded by open land. Again the colonies were in place with a set flight pattern before apples bloomed and trapped samples were taken. Competing plants included: yellow rocket, honeysuckle, dandelion, and horse chestnut pollen. An average of 60.0 percent apple pollen was obtained from two samples, indicating that apple can compete very well for bee visits.

The third orchard was the largest being in the center of a large acreage of commercial production. Bees were placed in the center of this orchard. Contrary to expectations, apple provided only 25.0 percent of the pollen and much foreign pollen appeared in the traps. Willow provided the greatest amount of pollen,

TABLE 9

Percent of Different Pollens Gathered by Colonies in Apple Orchards During the Period of Bloom in 1971

Orchard (Collection dates)	Sample	Apple *Pyrus malus* L.	Willow *Salix* spp. L.	Yellow Rocket *Barbarea vulgaris* R. Br.	Dandelion *Taraxacum officinale* Weber	Honeysuckle *Lonicera* spp. L.	Horse Chestnut *Aesculus hippocastanum* L.	Pine *Pinus* spp. L.	Undetermined
1. Galesburg	A	55.1	2.7	33.7	8.5			1.6	
(May 14-	B	66.1	7.8	17.0	7.5			0.8	
May 20)	Mean	60.6	5.3	25.3	8.0				
2. Ovid	A	58.7		21.4	10.0	9.5	.4		
(May 21-	B	61.2		16.3	7.3	13.9	1.3		
May 27)	Mean	59.9		18.9	8.7	11.7	0.8		
3. Bailey	A	27.2	67.2		4.6	1.0			
(May 20-	B	22.9	53.9	1.0	9.1	8.1			5.0
May 28)	Mean	25.0	60.6	0.5	6.8	4.6			2.5
	Grand Mean	48.5	21.9	14.9	7.8	5.4	<1.0	<1.0	1.2

indicating a serious competition for bee visits in that location. Dandelion, honeysuckle, and yellow rocket also provided pollen.

Plants Competitive to Blueberry Pollination - Table 10 gives the percentage of different pollens in the sample collected from a colony of bees placed in blueberries (*Vaccinium corymbosum* L.). Reference to this table shows that competing plants near blueberries can reduce the number of bees working the crop for pollen. In assessing this information it is necessary to keep in mind that most honey bees work blueberries for nectar, which is relatively attractive. Shaw, *et al* (1954) stated that only four percent of bees taken on blueberries carried pollen in their baskets. Two plants, gray dogwood and cherry (*Prunus avium* L.) were major competitiors for visits of pollen-collecting bees. Minor competitors included willow, narcissus (*Narcissus* sp. L.), wild cherry, and white clover. Because bees require large amounts of pollen during their build-up period in May and blueberry does not provide it, visits to other plants must be considered a necessity.

Plants Competitive to Strawberry Pollination - Front entrance pollen traps were used to collect pollen from colonies in strawberries (*Fragaris* hybrid L.). They are easy to install and pollen is easily removed with little hive manipulation. Because these traps removed a much smaller percentage of pollen pellets than the O.A.C. traps, weights of pollen collected were not recorded. The sample size collected was large enough so that a minimum of 300 pellets could be identified which is considered an adequate random sample for representation of plants visited for pollen by the bees.

Table 10

Percent of Different Pollens Gathered By Colonies in a Blueberry Field During the Period of Bloom in 1971

Plant Name	Scientific Name	Percent
Blueberry	*Vaccinium corymbosum* L.	8.7
Gray Dogwood	*Cornus racemosa* Lam.	34.5
Cherry	*Prunus avium* L.	33.8
Willow	*Salix* spp. L.	7.8
Narcissus	*Narcissus* spp. L.	7.7
Black Cherry	*Prunus serotina* Ehrh.	5.6
White Clover	*Trifolium repens* L.	1.9

Table 11 gives the percentage of each type of pollen found at each location which indicates the relative importance of the plants that were competing with strawberries for bee visits. Field one was surrounded by woods, swamps, and orchards. Strawberry yielded 54.3 percent of the pollen samples with wild cherry being a major competitor. Dandelion and sweet cherry yielded large amounts and a few pellets of pine and trillium pollen were gathered. A week later in the same location the surrounding vegetation in bloom had changed and apple, yellow rocket and a mustard became major competitors along with wild cherry. Small amounts of pollen were also obtained from willow. Dandelion had ceased bloom.

Field two was mainly of the Redchief variety which was apparently less attractive to bees than Midway 1 or Midway 2. An average of 2.9 percent strawberry pollen was trapped which confirmed observations of few pollen collecting bee visits in the field. Black cherry provided 72.9 percent of the pollen and must be considered an important competitor for pollinators of strawberries or other commercial fruit in the area. Willow also provided much pollen and should be considered a major competitor. Less competitive for the time and location included dandelion, white clover, and honeysuckle.

Samples were collected from field one such that strawberry pollen gathering could be compared in the morning and afternoon (Table 12). The 40.1 percent mean value in the morning is significantly less than the 61.8 percent gathered in the afternoon at the five percent level by the paired-t test. This indicates that peak pollen collecting in strawberries is in the afternoon.

TABLE 11

Percent of Different Pollens Gathered by Colonies in Strawberry Fields During the Period of Bloom in 1971

Field	Date	Location	Time	Strawberry *Fragaria virginiana* hybrid Duchesne	Black Cherry *Prunus serotina* Ehrh.	Sweet Cherry *Prunus avium* L.	Apple *Pyrus malus* L.	Dandelion *Taraxacum officinale* Weber	Yellow Rocket *Barbarea vulgaris* R. Br.	Mustard *Brassica* spp. L.	Willow *Salix* spp. L.	Others*
Field #1	May 23	North	am	48.4	39.6			12.0				
				63.2	29.3			7.5				
			pm	73.7	22.0	3.8		1.0				
		Central	am	84.3	10.9			3.8				1.0[2]
			am	34.9	35.4	2.6		27.2				
			pm	49.8	44.4	4.5		1.2				
		South	am	27.6		8.5		63.8				.3[1]
			pm	85.6		3.1		11.3				
			pm	50.1	28.0			21.2				.5[1]
		Mean		57.5	23.3	2.5		16.6				
	June 3	North	am	39.4				.3		58.0	2.3	
			am	59.2		30.1	6.4			4.0		.3[3]
			pm	45.6	32.3	6.7	11.9			3.5		
			pm	17.8	4.6		15.6			61.8		
		Central	am	6.3			63.0		22.0	7.7		1.0[1]
			am	70.2			2.2	3.8	23.9			
			am	90.7			2.2		1.2	.3		5.6[3]
			pm	84.7						13.9	1.4	
			pm	88.0			4.7		5.0	1.2		.9[3]
		South	am		26.5		72.5					1.2[3]
			pm	66.1	4.4		10.7		17.4	.6		.9
		Mean		51.6	6.2	3.3	17.2	0.4	6.3	13.7	0.3	
Field #2	June 1		pm	3.9	62.0		8.8		5.2	.6	19.6	
			pm	1.9	81.0		2.7	.9			13.3	.3[4]
			pm		75.6						23.7	.7[5]
		Mean		1.9	72.9		3.8	0.3	1.7	0.2	18.9	
		Grand Mean		47.2	21.6	2.6	8.7	6.7	3.3	6.6	2.6	0.6

1. Pine *Pinus* sp. L.
2. Trillium *Trillium* sp. L.
3. Mustard *Brassica* sp.
4. White clover *Trifolium repens* L.
5. Honeysuckle *Lonicera* sp. L.

Table 12

Percent of Strawberry Pollen Gathered by Colonies in the Morning and the Afternoon During the Bloom Period in 1971

Date and Location		Morning 8-12 am	Afternoon 12-4 pm
May 28	North	48.4	68.2*
	Center	59.6*	49.8
	South	27.6	67.8*
June 3	North	49.4*	31.7*
	Center	55.7*	86.4*
	South	0	66.1
	Mean	40.1	61.7**

*Average of two samples.

**Significantly larger at the 5 percent level by the paired-t test.

Plants Competitive to Cucumber Pollination - Collison and Martin (1970) reported very little cucumber pollen gathered by bees in cucumber fields. My data showed no cucumber pollen in traps. Bees working cucumber were rarely found to collect pollen, and pellets which were found were so small that bees may have passed through the trap and retained the pellets. Connor and Martin (1970) reported that practically all bees visiting cucumbers were collecting nectar.

Table 13 lists the pollens found in the traps and gives the percentage of each type. Colonies in cucumber fields in August collected mostly red clover and goldenrod pollens. Minor sources included alsike clover, teasel, and Queen Anne's lace. The land surrounding the fields was dominated by two other crops, corn and beans. Corn pollen was in the sample from two locations but in low quantity indicating it was past peak bloom. Field bean pollen was not found even though bees were observed working it, possibly because the pellets were small or bees were working it for nectar. Besides the agricultural crops, several roadside and woodland weeds were present that provided less than five percent of the total sample. These included chicory, smartweed, burdock, ragweed, sow thistle, and touch-me-not. These plants are not strictly competitive because colonies need pollen and cucumber does not supply it.

TABLE 13

Percent of Different Pollens Gathered by Colonies in Cucumber Fields During the Bloom Period in 1971

Date:	Aug. 13-19		Aug. 13-20		Aug. 13-24		Aug. 19-Sept. 1		Mean
Sample:	A	B	A	B	A	B	A	B	
Red clover	2.5	Sample Lost	80.1	51.6	24.9	94.1	9.3	1.5	37.7
Goldenrod			13.6	23.9			54.1	48.1	20.0
Alsike clover	21.9		1.6	2.5	4.2	1.0	11.1	24.4	9.5
Teasel	37.6				10.9	2.3			7.3
Queen Anne's lace	13.8			2.2	26.5		.8		6.2
Chicory					3.8		7.7	23.1	4.9
Smartweed				9.2	1.0		7.4	1.8	2.8
Burdock			3.5				7.9	.9	1.8
Corn	10.7				1.6	.3			1.8
Ragweed	.3		.3	10.3	1.0	.3			1.7
Sow thistle	1.9		1.1	.3	7.7				1.6
Touch-me-not			3.8				3.2	1.7	1.2
Cucumber	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0

CHAPTER 7

PERIODICITY AND AMOUNT OF POLLEN FLOW

INTRODUCTION

Knowledge of pollen flows, pollen sources, and pollen needs of the colony are important to successful beekeeping, to choosing an apiary site, to efficient pollination, and particularly to the successful build-up of colonies in the spring. More and more interest is being demonstrated in large-scale collection of pollen for sale to supplement colony requirements and in some countries for human food. This results in the need for information on how much pollen is available from different floral sources, from different races of bees, from trapping at different times of day, and from different geographical locations. Also as population increases and land-use patterns change, favorable bee pasture becomes more scarce, and the need to inventory our resources becomes more pressing.

LITERATURE

The presence of brood in a colony is a stimulus for pollen gathering. Todd and Bishop (1946) found that during winter when brood rearing was at its lowest, very little pollen was being consumed, and then during peak brood rearing a large intake of pollen was noted which was quickly eaten. English (1946) also showed this relationship by overwintering some colonies with 600 square inches of pollen and others with little pollen and found that the colonies with ample supplies had twice as much brood at the end of May as those with negligible supplies. Vansell and Todd (1948) reported that the rearing of a frame of brood required about a frame of pollen. Todd and Bishop (1946) said one pound of pollen will raise about 4,540 bees, and with 200,000 bees reared by a strong colony during a year, 44 pounds of pollen would be required per season. Therefore, the amount of pollen available, or the lack of natural pollen, directly influences colony strength.

There are several factors that determine the amount of pollen gathered by a colony. Those studied here include seasonal blooming trends, strain of bee used, time of day of collection, and location of the colonies. Other factors may be the biological value of the pollen for the bee (Maurizio, 1951), the amount of brood present in the colony, or the proportion of field bees concentrating on nectar gathering. Strong colonies are of course capable of collecting more pollen than weak ones.

Examining seasonal trends, Todd and Bishop (1946); Nye and Mackensen (1965) and Louveaux (1954) all reported that colonies side by side in an apiary can gather very different kinds and amounts of pollen. This may be because of conditions such as colony strength, amount of brood, colony morale, queenlessness, flight patterns, chance encounter, available pollen sources, and other colony conditions. However, when the colony's seasonal trends are compared, they are very similar (Nolan, 1923; Louveaux, 1954, Louveaux, 1959; and Brown, 1967). Pollen flow cycles are determined by the blooming succession of the flora in the area and the rhythm of the colony, e.g., in early spring, pollen is in great demand for brood rearing, but in June and July the emphasis is on nectar-gathering (Percival, 1955); therefore, depending on the time of the season pollen is trapped, large differences in pollen collected occur.

A second consideration is the genetic strain of bee used. Strains of bees vary in their preference for certain pollens, and the prevalence of a certain plant species may result in a large volume of pollen being gathered. Mackensen and Nye (1968, 1969 and 1970) selected certain strains of honey bees with a preference for alfalfa pollen and demonstrated that the trait was heritable. Since that time several seed companies and Dadant and Sons of Hamilton, Illinois cooperated to finance an extensive breeding program aimed at mass production of the alfalfa pollen collecting bee. G. H. Cale of Dadant and Sons was in charge of the breeding program which has now been discontinued for lack of funds. Such work may have led to the breeding of strains of honey bees particularly adapted by pollen preference to other crops.

A third consideration in the amount of pollen gathered is the time of day pollen is collected. Vansell and Todd (1948) noted that pollen income throughout a day was not constant. Certain plants provided relatively more pollen than others, and the main pollen flow would be during the periods in which the main plant species present their pollen. Parker (1926) listed certain plants that shed pollen in the morning (corn and ragweed) and others (sweet clover and white clover) that shed pollen most of the day. Thus variable amounts of pollen will frequently be gathered throughout the day.

A fourth consideration is the location of the colonies. Vansell and Todd (1948) trapped pollen in 18 western localities. These varied from 9 to 70 pounds per year in the amount of pollen gathered. Riedel and Wilson (1967) trapped pollen at four altitudes and found the highest elevation unable to sustain colonies because of lack of pollen for brood rearing. Also, several authors have shown that by placing colonies close to some crops, considerably more pollen will be gathered from that crop.

METHODS

Pollen was trapped for three seasons using the O.A.C. pollen trap at the Michigan State University Apiary. Smith (1965) claimed that this trap removed about 66 percent of the pellets from the bees. Trapped pollen was weighed in grams (Fig. 3) and a subsample saved for future identification. Scale colony weight records were also taken during this period, to help determine the interrelationships between nectar and pollen gathering. Also in 1970 colony strength measurements of the 10 colonies were taken on seven dates throughout the summer to help explain differences that might occur in pollen gathering due to colony strength. Brood area in square inches was made by measuring the total area of brood on each frame in the hive. An estimate of the number of bees in a colony was made by comparing the density of bees on each frame to a series of pictures of frames containing known number of bees, prepared by E. P. Jeffree of the North Scotland College of Agriculture. These estimates were then totaled to determine colony strength.

In 1969 five colonies were used and samples were collected at five-day intervals. In 1970 pollen was collected from two colonies twice a day for five days a week. In 1971 pollen was collected from two colonies once a week. Seasonal pollen flow trends were established from data accumulated during these three seasons.

Two races of honey bees were used in the summer of 1970 to assess possible racial preferences for different pollens. From the sampling sequence outlined in Chapter 3, pollen weights would give a good indication of the actual differences between the five colonies of these two races as to the amount of pollen gathered, assuming each race made pollen pellets of equal size.

By trapping pollen from colonies each morning and afternoon in 1970 it was possible to establish diurnal fluctuations in availability and amount of pollen collected. The same trapping sequence was used for this study as in the racial comparison study. Weekly morning and afternoon totals were analyzed by the paired-t test to test for significant differences.

In 1971 pollen flows were studied at the five locations mentioned in Chapter 5. Pollen was collected at weekly intervals from two colonies at each location. The weight of pollen from the colony that gathered the most pollen was used for analysis as this amount was most indicative of the pollen gathering potential of the area.

In each of these studies, the pollen trapped to determine pollen weight measurements was also identified to determine periodicity of flows.

RESULTS AND DISCUSSION

Assessment of Some Factors Which Influence the Amount of Pollen Gathered

Honey Flow - Honey flow (actually total weight change of a colony) was measured by the use of a scale hive. At five day intervals, the weight of the colony was measured in pounds. A three-year average was then prepared (Fig. 9) showing the net weight gain or loss recorded. In early spring, the bees depleted the previous year's stores faster than they were replaced. By mid-May sufficient field bees were present to gather excess nectar from the numerous honey plants. From late June through mid-July the main honey flow occurred. The typical August decline followed when few nectar plants bloomed, and weather did not generally favor bee flight. During early September the main fall flow occurred (mainly goldenrod and aster). Each peak of honey flow can be correlated to the bloom of specific plants. However, the intent here was to determine when peak honey flows occurred in relation to peak pollen flows.

Brood Measurements - The presence of brood and a queen in a colony are stimuli for pollen gathering (Free, 1967 and Jaycox, 1970). By measuring the amount of brood present in colonies, the relative amount of pollen that will be gathered can be predicted. This indicates the efficiency of the colony in crop pollination. Table 14 lists measurements of the brood area for each colony on each date sampled. When statistical analysis (Student's t-distribution) was applied to this data, no significant differences in brood area existed between the races on any of the sampling dates. However, after July 3, only four Carniolan colonies were used as one colony became queenless

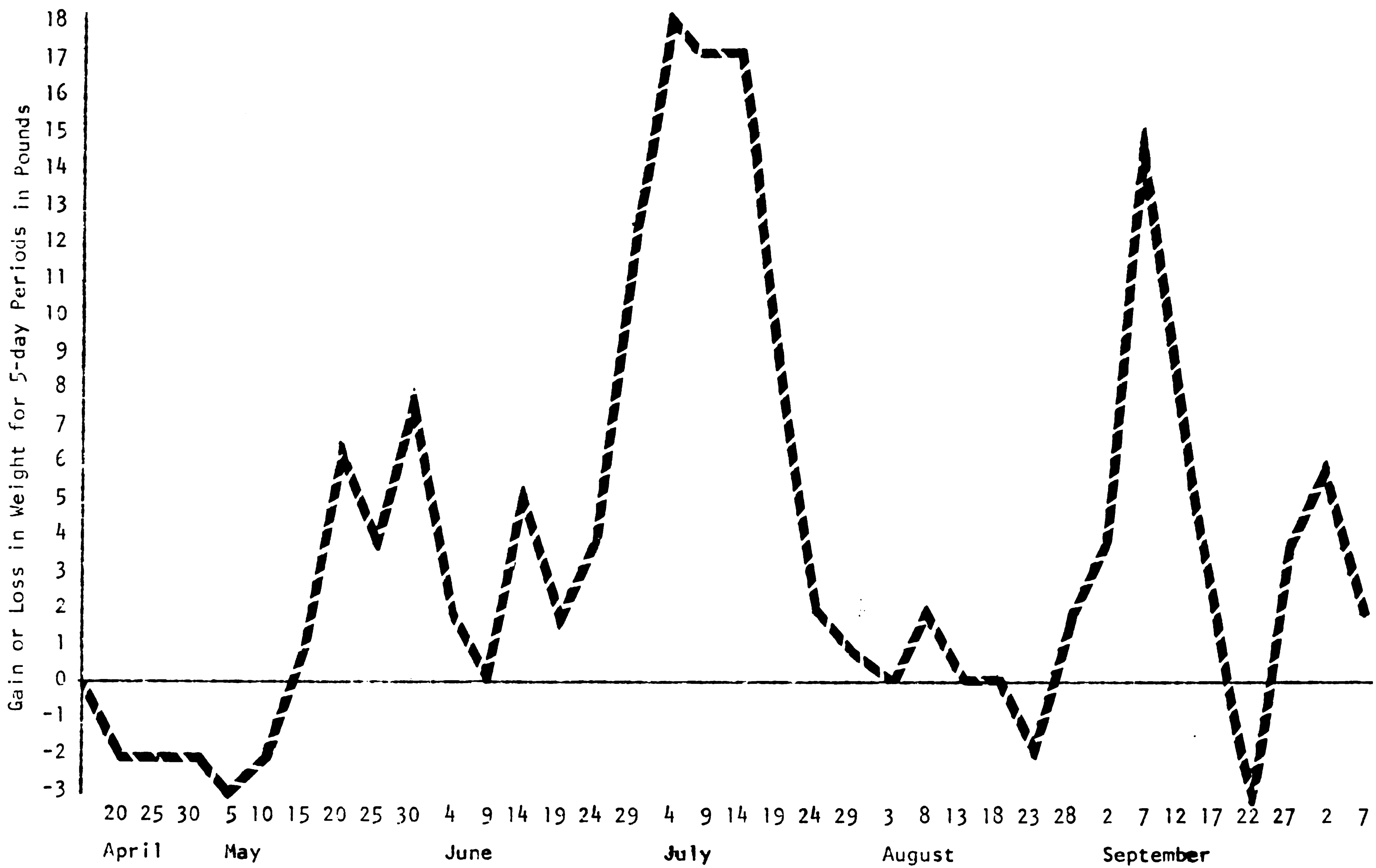

Fig. 9. Three Year Average (1969-1971) of Scale Colony Weight Gain or Loss at the MSU Apiary.

Table 14

Measurements of Brood Area in Carniolan and Italian Colonies in 1970 at the MSU Apiary

	April 29	May 18	June 19	July 3	July 27	August 12	September 15
Colony No.	Sq. in. Brood	Sq. in. Brood	Sq. in. Brood	Sq. in. Brood	Sq. in. Brood	Sq. in. Brood	Sq. in. Brood
Carniolan							
10	473	760	882	826	822	640	521
12	535	902	1,268	977	772	1,213	787
15	571	498	1,050	335	726	747	926
17	574	946	1,021	328	1,083	874	1,047
26	649	1,231	1,401	289	46*	37*	0*
Total	2,802	4,337	5,622	2,755	3,403	3,474	3,281
Mean	560.4	867.4	1,124.4	551.0	850.7	868.5	820.2
S.D.	64.1	268.1	207.4	324.8	159.7	248.8	226.0
Italian							
2	516	711	1,503	1,214	1,048	959	1,202
3	572	901	581	765	677	748	670
11	409	738	684	789	631	555	0*
14	487	516	490	289	996	1,193	1,192
24	691	1,487	1,356	1,131	1,055	866	759
Total	2,675	4,353	4,614	4,188	4,407	4,321	3,823
Mean	535.0	870.6	922.8	837.6	881.4	864.2	955.7
S.D.	105.2	370.7	470.5	366.2	209.5	237.8	280.9

*Colony queenless and measurements were not used in the totals.

and after August 12 only four Italian colonies were used. This data indicates that differences in pollen gathering between the races must be accounted for by some reason other than the amount of brood in the colonies.

Population Estimations - The strength of a colony along with the amount of brood present greatly influences the amount of pollen gathered. By having more bees in a colony, a larger field force is present, and more brood can be cared for and reared. Both of these factors serve to increase pollen gathering; therefore, colony population estimates were made (Table 16). Student's t-distribution test was applied to this data to test for significant differences in bee numbers between the two races. No differences were found until the last sampling date at which time the Italians had a significantly larger population at the 1% level than the Carniolans. Therefore, if any differences do occur in the amount of pollen gathered, they will have to be explained by factors other than colony strength.

Seasonal Trends in the Amount of Pollen Gathered

1969 Seasonal Pollen Flow - Five colonies were trapped and pollen collected every five days (Table 17) during the 1969 season. In May there were great fluctuations in the amount collected due mainly to variable weather conditions; however, a general trend was upwards until the highest spring peak occurred on May 30. After this there was a drastic decrease coinciding with the end of the fruit, maple, and dandelion bloom. A gradual increase occurred during June and peaked toward the end of June as the clovers came into bloom. From the beginning of July until July 19 a decrease

Table 15

Measurements of Number of Bees in Carniolan and Italian Colonies in 1970 at the MSU Apiary

Colony No.	April 29 No. of Bees	May 18 No. of Bees	June 19 No. of Bees	July 3 No. of Bees	July 27 No. of Bees	August 12 No. of Bees	September 15 No. of Bees
Carniolan							
10	4.900	11,000	13,000	13,088	12,670	11,100	9,030
12	7,200	13,900	19,300	17,700	21,730	21,100	10,500
15	4,800	15,800	23,300	20,360	15,810	16,805	14,100
17	6,900	13,100	21,200	20,400	16,930	16,500	14,300
26	5,900	22,500	30,100	20,801	6,130*	2,920*	0*
Total	29,700	76,400	106,900	92,349	67,140	65,505	47,930
Mean	5,950.0	15,280.0	21,380.0	18,469.8	16,785.0	16,376.2	11,982.5
S.D.	1,105.9	4,374.0	7,963.5	3,251.5	3,757.6	4,096.8	2,631.2
Italian							
2	6,700	16,100	29,500	28,730	26,600	30,330	21,530
3	8,000	25,700	29,900	26,000	19,000	18,980	17,200
11	7,300	14,700	19,700	14,280	13,200	16,867	10,470*
14	5,000	20,000	14,600	13,800	9,800	17,300	18,700
24	5,200	25,700	25,600	22,830	18,830	20,500	21,130
Total	32,200	102,200	119,300	105,640	87,430	103,977	78,560
Mean	6,440.0	20,440.0	23,860.0	21,128.0	17,486.0	20,795.4	19,640.0
S.D.	1,308.8	5,179.6	6,602.5	6,801.1	6,414.9	5,521.0	2,051.8**

*Colony queenless and measurements were not used in the totals.

**Italians were significantly larger at the 1% level than the Carniolans in number of bees.

Table 16

Seasonal Pollen Flow in Grams Per Day (1969-1971) at East Lansing[1]

	1969[2]		1970[3]		1971[4]		**Mean**[5]	
	Date	Weight	Date	Weight	Date	Weight	Date	**Weight**
April	20	-	18	2	15	3	15	**2.0**
	25	4	24	2	22	43	22	**18.0**
	30	32	1	7	29	1	29	**14.3**
May	5	102	8	5	6	46	6	**45.7**
	10	30	15	16	13	43	13	**40.0**
	15	92	22	35	20	44	20	**45.0**
	20	49	29	17	27	35	27	**67.0**
	25	103						
	30	193						
June	4	30	5	24	3	74	3	**68.0**
	9	39	12	48	10	59	10	**52.0**
	14	54	19	43	17	72	17	**62.0**
	19	67	26	20	24	71	24	**74.0**
	24	64	3	26				
	29	75						
July	4	36	10	8	1	50	1	**49.0**
	9	63	17	16	8	47	8	**40.7**
	14	21	24	26	15	27	15	**26.3**
	19	1	31	27	22	33	22	**19.7**
	24	3			29	39	29	**36.3**
	29	20						
August	3	51	7	30	5	135	5	**71.7**
	8	29	14	37	12	65	12	**55.3**
	13	54	21	37	19	83	19	**71.7**
	18	85	28	47	26	110	26	**76.7**
	23	74						
	28	75						
September	2	117	4	46	2	71	2	**76.0**
	7	217	11	51	9	61	9	**122.3**
	12	117	18	15	16	50	16	**64.3**
	17	100	25	20	23	55	23	**41.5**
	22				30	31	30	**23.5**
	27							
October	2		2	12	7	57	7	**44.5**
	7	75	9	43	14	17	14	**24.0**
	12	6	16	10	21	22	21	**18.0**
			30	1				

[1] Highest recorded weight in grams of colonies used.

[2] Based on 5 colonies collected at 5-day intervals.

[3] Based on 10 colonies collected Monday through Friday.

[4] Based on 2 colonies collected once a week.

[5] Average amount of pollen collected per colony for 3 years.

of pollen gathering occurred while bees concentrated on nectar gathering as supported by scale colony weights (Fig. 9). Then from mid July to mid-September a great increase occurred as fall plants came into full bloom. This was the greatest pollen flow of the year. After this peak a steady decrease occurred until mid-October when no plants were in bloom to provide pollen.

1970 Seasonal Pollen Flow - The 1970 season included daily trapping of pollen from ten different colonies Monday through Friday (Table 17). The same general increase in gathering occurred from April 14 until a peak was reached the third week of May. This was followed by a sudden decrease the next week when flowering of the major spring pollen sources ceased. A gradual decrease followed until July 10. This was again followed by a very constant two-month increase which peaked on September 11 with goldenrod in bloom. Again a gradual decrease occurred until late October except for one week in early October when asters were in bloom.

1971 Seasonal Pollen Flow - Two colonies were used in 1971 and pollen was collected once a week, with the greater amount of pollen collected of the two colonies recorded (Table 17). From April 15 through the first week of June, except for fluctuations due to weather, a large amount of pollen was gathered. A general decline followed until July 15 when the mid-summer low point was reached again as in the other years. From then until August 26 was a very high late summer early fall flow. After September 2 a gradual decrease occurred until mid-October, except for the first week of October when the asters were in bloom resulting in an exceptionally high collection. This trend was like the other years with the high and lows of gathering corresponding within one week.

Average Pollen Flow in East Lansing - Fig. 10 summarizes the three summers of pollen gathering, and shows seasonal trends at weekly intervals. Data was obtained by averaging the extrapolated values of the three years on specific dates. The pollen flow followed consistent trends for the three years with high and low values coinciding within a week, indicating from consistent blooming patterns in consecutive years.

The pollen flow followed a definite pattern with a spring increase from mid-April through the first week of June. Then a slight decrease occurred after the maple, fruit, and dandelion complex ended. Clovers were in flower from early June until late July and provided most of the early summer pollen. The mid-summer low occurred the third week of July. From then until the second week of September a steady increase occurred. Goldenrod was dominant during the latter part of this period. At this time more pollen came into the hive than at any other time of the year. From early September until late October a steady decrease of intake occurred as plants ceased blooming except for a very distinct peak that occurred the first week of October when the asters were in bloom.

Racial Differences in the Amount of Pollen Gathered

Recent selection of a strain of bees which gathers alfalfa pollen more effectively has shown that strains of bees may differ in their preference for different pollens and that the differences

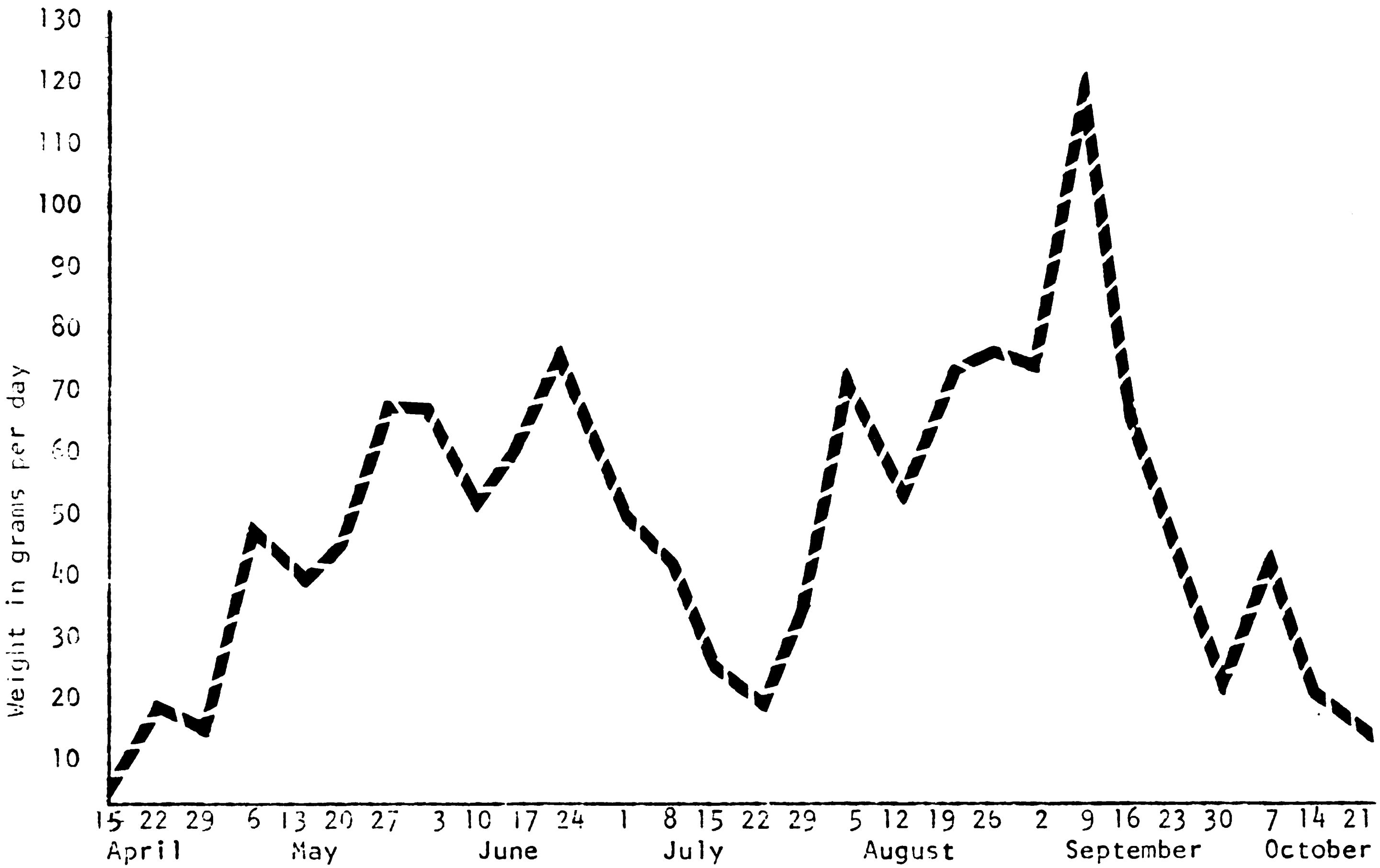

Fig. 10. Mean Weight of Pollen Gathered in East Lansing (1969-1971) at the MSU apiary.

are heritable. My experiment was carried out to compare the amount of pollen gathered by Carniolan and Italian colonies. Table 18 shows the amount of pollen each race gathered throughout the season for morning and afternoon samples at weekly intervals. Again the bimodal distribution was present with a spring and fall peak in pollen gathering separated by a mid-July reduction of pollen gathering. The spring weights were not recorded as six weeks were allowed after requeening for the new queen's progeny to reach the adult stage. From June 6 until October 3, the Italians gathered significantly more pollen than did the Carniolans. A paired-t calculated value of 4.94 was highly significant at the 1 percent level. Then from October 3 until the end of the season on October 31, the Carniolans gathered more pollen than did the Italians even though there was no difference in the brood areas and the Italians had a significantly (1 percent confidence level) larger population. The reason for this is that the Carniolans gathered substantially more aster pollen. This supports an old theory that in their ancestry they relied mainly on fall pollen sources to overwinter, because their tendency to swarm left little reserve for wintering. By having large stores for overwintering, they tend to build up quickly in the spring. By looking at the total weights collected the Italians gathered more, but not significantly more than the Carniolans (2889 and 2465 grams respectively). Also both races gathered more in the morning than they did in the afternoon.

Morning and Afternoon Differences in the Amount of Pollen Gathered

Honey bees generally gather more pollen in the morning than in the afternoon. Data from this experiment (Table 19) supports this common opinion. The seasonal morning total pollen intake was 2467

Table 17

Weight of Pollen Collected Per Day By Two Races of Bees in 1970 at the MSU Apiary[1].

		Italian			Carniolan		
		A.M.	P.M.	Total	A.M.	P.M.	Total
June	7-13	172	144	316	145	118	263
	14-20	80	79	159	51	36	87
	21-27	82	42	124	42	27	69
July	28- 4	80	89	169	45	35	80
	5-11	31	13	44	26	21	47
	12-18	65	39	104	34	14	48
	19-25	53	89	142	54	40	94
	26- 1	90	76	166	71	62	133
August	2- 8	134	54	188	69	44	113
	9-15	147	39	186	104	57	161
	16-22	159	19	178	115	37	152
	23-29	145	64	209	132	105	237
September	30- 5	111	145	256	85	92	177
	6-12	84	213	297	95	47	142
	13-19	5	83	88	0	64	64
	20-26	74	51	125	50	16	66
October	27- 3	31	27	58	33	52	85
	4-10	35	12	47	139	159	298
	11-17	3	10	13	12	63	75
	18-24	4	9	13	17	47	64
	25-31	5	2	7	7	3	10
Seasonal Flow		1590	1299	2889	1326	1139	2465

[1]Pollen was trapped Monday-Friday with weight recorded in grams.

TABLE 18

Morning and Afternoon Pollen Collection Per Day (in Grams) in 1970 at the MSU Apiary

	Date	A.M.[1]	P.M.[2]
April	14-18	5	9.5
	20-24	26.5	15
	27- 1	34	16.5
May	4- 8	19.5	12.5
	11-15	26	98
	18-22	141	106
	25-29	69	48
June	2- 5	90	78
	8-12	183	154
	15-19	80	80
	22-26	90	48
	29- 3	94	99
July	6-10	38	23
	13-17	73	41
	20-24	84	97
	27-31	96	90
August	3- 7	141	68
	10-14	181	77
	17-21	212	45
	24-28	205	117
September	31- 4	140	181
	7-11	143	213
	14-18	5	99
	21-25	82	58
	28- 2	34	52
October	5- 9	139	159
	12-16	12	63
	19-23	17	47
	26-30	7	3
Seasonal Flow in Grams		2467	2197.5

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[1]Sunrise until 1 p.m.

[2]1 p.m. until sunset.

grams and the seasonal afternoon total pollen intake was 2197 grams. This was not a significant overall difference (paired-t test; 30 percent level) but the data indicates that two periods of flow exist. From April 18 until September 4, the morning flow was greater than the afternoon flow except for weather conditions such as cold mornings or rain. The average difference throughout this period was 28.3 grams per week. The paired-t test gave a significant difference at the 2 percent level. After September 4 the trend reversed and the afternoon flow became greater than the morning flow. The average difference throughout this period was 33.3 grams per week. Again a significant difference was obtained by the paired-t at the 5 percent level with a calculated-t = 2.72 and a tabular-t .05(8) = 2.31. This trend continued until the end of the season on October 30, during which period asters supplied most of the pollen.

Another interesting observation can be made during August. A great difference occurred between the weights of the morning and afternoon samples. It was reported that some plants (goldenrod included) shed their pollen mainly in the morning. Apparently in August the major source of pollen was from goldenrod and most of the pollen was collected in the morning with little for the bees to gather the rest of the day. This trend was not obvious the remainder of the fall season.

Locational Differences in the Amount of Pollen Gathered

The amount of pollen gathered by a colony may indicate the availability of pollen in a particular location. Fig. 11 shows the higher amount of pollen collected each month for two colonies at

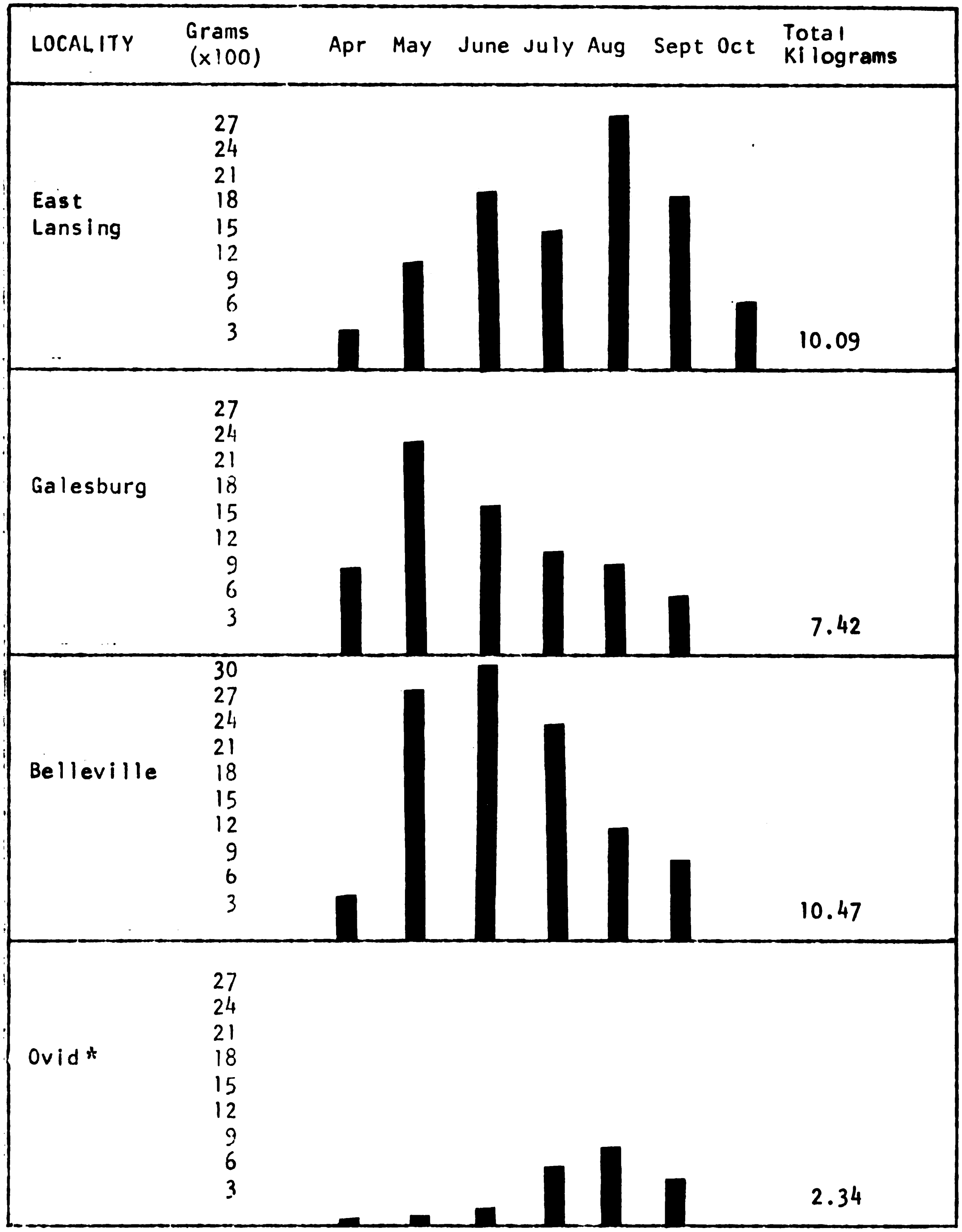

Fig. 11. Comparative Pollen Flows by Months at Four Localities in Southern Michigan in 1971. (Higher weight of two colonies).

* Bees bypassed the trap through openings in the hive.

each of four locations in Michigan. Differences in these locations are probably due to local flora, but weather factors and colony conditions may be other variables to consider. East Lansing showed the typical biomodal distribution that was discussed under Seasonal Trends in Pollen Gathering. The Galesburg and Belleville locations, however, show a trend skewed to the right. There was a rapid increase in gathering in the spring that peaked in May or June. Then a gradual decrease occurred through the rest of the season. The Ovid sample was not truly representative of the area. Bees were entering the hive loaded with pollen through cracks between the bodies and ventilation holes in the supers which resulted in a very low trap catch. This data indicates that the bimodal distribution of pollen gathering in East Lansing for three years might not be the truly typical state-wide situation.

CHAPTER 8

SUMMARY AND CONCLUSIONS

Collection and Identification of Bee-Gathered Pollen

Identification of unknown bee-gathered pollen by comparison with reference pollen slides can be performed with great reliability. The acetolysis process does aid in the identification by leaving very clean pollen grains that have no organic matrix to conceal the surface sculpturing. Because of the consistency in color of pollen pellets within a plant species at each collection, they could be sorted by color to species. The availability of the Scanning Electron Microscope was a valuable tool in the identification of pollen grains.

Pollen gathered by honey bees was trapped using the O.A.C. pollen trap. This trap proved to be more useful and adaptable for this purpose than other traps used, and is recommended for use in experiments similar to this in the future. It has been criticized for use when pollen is fed back to bees because refuse from the hive drops into it, possibly including disease material.

Calendar of Pollen Plants in East Lansing

A phenological chart of the pollen gathered by bees in East Lansing was prepared which determined time and duration of bloom for each species. An example that illustrates this was the corn pollen flow which showed three peaks in 1970 as different fields came into bloom.

The most important sources of pollen were determined each week throughout the season. The most important pollen source in East Lansing was the goldenrod-aster complex. Other species which provided more than five percent of the seasons total supply were alsike and white clovers. Certain plants provided more pollen than anticipated (i.e. sumac, corn, Queen Anne's lace, burdock) while others proved to be less important than expected (i.e. dandelion).

Differences did occur between the two years in pollen flow in East Lansing. Willow and aster pollen were much more prevalent in the 1971 samples and white clover, maple and charlock were more prevalent in the 1970 sample. The reason for charlock providing more pollen in the 1970 season was due mainly to a five-acre research plot near the apiary. All other differences were minor and due mainly to cultural practices and weather patterns.

Collection of Pollen by Colonies of Two Races

In general Italian and Carniolan colonies gathered the same amounts of pollen from the same plant species. It appeared that when plants were in bloom, bees of either race visited them based on characteristics associated with bee behavior and pollen attractiveness. However, there was limited evidence of some racial divergence in pollen preference under the conditions of this test. Italians gathered significantly more pollen from corn, Queen Anne's lace, red clover, and ragweed and less from sow thistle, white clover, aster, and bull thistle than the Carniolan colonies. If such differences in racial preferences were consistent this indicates possibilities for practical use such as in avoiding pesticide poisoning by using a race which does not favor certain crops which may present a pesticide hazard (e.g. corn) or efficiency in pollinating certain crops.

Morning and Afternoon Pollen Gathering

The study to determine what time of day bees gather pollen from specific sources revealed most pollen sources (i.e. dandelion, goldenrod, clovers) present their pollen throughout the day. However, certain plants yielded significantly more pollen in the morning (i.e. corn, charlock, sow thistle, Queen Anne's lace and ragweed) while others provided significantly more pollen in the afternoon (i.e. aster, burdock, sweet clovers, bull thistle, and red clover).

Comparison of Pollen Gathering Patterns in Four Locations in Southern Michigan

Pollen was gathered at four sites in southern Michigan in 1971 and seasonal patterns in pollen collection were determined. At each location different species provided the greatest amount of pollen. However, the aster-goldenrod and clover complexes were the most prevalent at all four locations. Fifteen species provided two-thirds of all the pollen gathered at the four locations.

Plants Which Compete for Bee Visits to Pollinated Crops

One factor of crop pollination, that of plants competitive for bee visits, was studied briefly. Plants competitive to certain pollinated crops were determined by trapping pollen from colonies placed in the target crop during bloom.

Apples appear to compete well for bee visits with other plants which bloom at the same period. Minor competitors were yellow rocket, dandelion and honeysuckle but they vary in importance depending on the orchard site.

Blueberries do not compete well for pollen-collecting bee visits. Many plants in the vicinity can compete and will provide more pollen, but good pollination is nevertheless accomplished by bees working blueberries for nectar.

Strawberries compete well for pollen-gathering bees but tree fruits, willow, dandelion and yellow rocket pollen was gathered by colonies located in strawberry fields. On the average, the percentage of strawberry pollen gathered by honey bees was higher, relative to other plants, in the afternoon than in the morning. Redchief variety rated low in attractiveness to honey bees.

Honey bees are effective pollinators of cucumbers; however, no cucumber pollen was collected in the pollen traps on colonies adjacent to cucumber fields. Depending on the location of the fields in relation to surrounding flora, and the time of year the cucumbers are in bloom, different plants will be major competitors to cucumber pollination. In this study red clover and goldenrod were the major competitors for bee visits.

Periodicity of Pollen Flow

To determine the availability of pollen, several studies were conducted in East Lansing. Specific factors which could reduce the amount of pollen gathered such as the honey flow and colony strength were studied. Three year's honey flow data indicated that peak nectar collection in mid-summer coincided with the low point in pollen gathering, indicating the bees switch to nectar gathering when major flows occur. However, in the fall both nectar and pollen flows peaked at the same time. Colony strength measurements of brood area and population size indicated that no differences occurred between the two races, so differences in the amount of pollen gathered must be accounted for by some reason other than colony strength.

The seasonal trend in pollen gathering in East Lansing was a bimodel distribution. Peak flows occurred in spring, with a summer decline followed by a higher peak in the fall. The total flow was probably reduced due to cultural and cropping practices on campus such as cutting roadside weeds, clean cultivation, and mowing the lawns all which reduce the number of plants which provide pollen and nectar.

When comparing races of honey bees, Carniolan and Italian strains gathered the same amount of pollen. However, from early June to early October, the Italians gathered more pollen, and from then until the end of the season the Carniolans gathered more.

Both races gathered more total pollen in the morning than the afternoon. Although this was not a significant trend for the total season, when the data was examined prior to early September and after early September the trends became significant. Prior to that date, the bees gathered significantly more pollen in the morning, and after that date they gathered significantly more in the afternoon. Plants generally present their fresh pollen in the morning when the flowers open, but late in the season mornings are too cool for active bee foraging, so the major flow occurs in the afternoon.

Differences do occur in pollen flow at different locations around the state. The samples indicated a bimodel distribution for the East Lansing area and askewed to the right distribution peaking in late May in Galesburg and June in Belleville. The amount of pollen gathered at the four locations ranged from 5.2 pounds to 23.1 pounds, with reasons for the range being that certain locations have more available pollen and that some of the equipment was inferior and allowed the bees to bypass the pollen trap. This data indicates that the bimodel distribution of pollen gathering in East Lansing for three years might not be the typical statewide situation.

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APPENDIX I

SEM PHOTOGRAPHS OF MICHIGAN POLLEN GRAINS[1,2]

GRAMINAE (Grass Family)

Fig. 1. Corn. Zea mays L. Coll. E. Lansing, MI. (Specimen acetolysed). Magnified 1,000x. About 120 microns. Monoporate. Sculpturing faintly granular appearance. Shape spherical.

PORTULACACEAE (Purslane Family)

Fig. 2. Spring Beauty. Claytonia virginica L. Coll. E. Lansing, MI. (Specimen acetolysed). Magnified 2,000x. About 45 microns. Tricolpate.' Exine tectate. Spherical. Furrows long and polar area small.

CRUCIFERAE (Mustard Family)

Fig. 3. Charlock. Brassica kaber (D.C.) L. Wheeler. Coll. E. Lansing, MI. (Specimen acetolysed). Magnified 2,000x. About 25 microns. Tricolpate. Reticulate. Spherical.

Fig. 4. Charlock. Same pollen grain magnified at 5,000x showing columella and reticula.

ROSACEAE (Rose Family)

Fig. 5. Strawberry. Fragaria virginiana L. var. Midway 11. Coll. Keeler, MI. (Specimen acetolysed). Magnified 2,000x. About 17 microns. Tricolpate. Exine strongly striate. Spherical.

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[1] Scientific nomenclature for plants based on "Manual of Vascular Plants" by Gleason, H. A. and A. Cronquist. D. Van Nostrand Company, Inc., Princeton, New Jersey. 1965.

[2] Description for pollen grains taken from "How to Know Pollen and Spores" by R. O. Kapp. Wm. C. Brown Company Publishers, Dubuque, Iowa. 1969.

Fig. 6. Apple. Pyrus malus L. var. Greening. Coll. Ovid, MI. (Specimen acetolysed). Magnified 1,000x. About 37 microns. Tricolporate. Furrows apparently interrupted at the equator by a weakly developed pore. Exine tectate, with faint striations. Shape prolate.

FABACEAE (Pea Family)

Fig. 7. White Clover. Trifolium repens L Coll. E. Lansing, MI. (Specimen acetolysed). Magnified 3,000x. About 25 x 18 microns. Tricolporate. Exine tectate. Reticulate. Shape prolate.

Fig. 8. Alsike Clover. Trifolium hybridum L. Coll. E. Lansing, MI. (Specimen acetolysed). Magnified 3,000x. About 25 x 18 microns. Tricolporate. Exine tectate. Reticulate. Shape prolate.

Fig. 9. White Sweet Clover. Melilotus alba (L) Desr. Coll. E. Lansing, MI. (Specimen acetolysed). Magnified about 2,000x. About 23 x 17 microns. Tricolporate. Exine tectate. Reticular. Shape prolate.

Fig. 10. Yellow Sweet Clover. Melilotus officinale (L) Desr. Coll. E. Lansing, MI. (Specimen acetolysed). Magnified 5,000x. About 23 x 17 microns. Tricolporate. Exine tectate. Reticulate. Shape prolate.

ANACARDIACEAE (Sumac Family)

Fig. 11. Smooth Sumac. Rhus glabra L. Coll. E. Lansing, MI. (Specimen acetolysed). Magnified 2,000x. Polar axis 43 microns., equatorial diameter 32 microns. Tricolporate. Furrows long, polar area small; transverse furrows rectangular. Exine tectate, columellae produce vague striate pattern. Shape subprolate.

ACERACEAE (Maple Family)

Fig. 12. Silver Maple. Acer saccharinum L. Coll. E. Lansing, MI. (Specimen acetolysed). Magnified 2,000x. About 27 microns. Tricolpate. Exine finely striate. Nearly spheroid.

Fig. 13. Box Elder. Acer negundo L. Coll. E. Lansing, MI. (Specimen acetolysed). Magnified 2,000x. About 27 microns. Tricolpate. Exine indistinctly tectate with short irregular swirls. Nearly spheroid.

UMBELLIFERAE (Carrot Family)

Fig. 14. Queen Anne's Lace or Wild Carrot. Daucus carota L. Coll. E. Lansing, MI. (Specimen acetolysed). Magnified 2,000x Polar axis 20 microns, equatorial diameter 10 microns. Tricolporate. Exine tectate. Prolate, much like a peanut shell.

ASCLEPIADACEAE (Milkweed Family)

Fig. 15. Milkweed. Asclepias syriaca L. Coll. E. Lansing, MI. (Fresh sample). Magnified 50x. Pollinium 590 x 1350 microns, contains about 250 pollen grains. Polyads tear-drop shaped, extracted from flower in pairs. Pollinia observed on many bees working this species for nectar. Photograph made available by Dr. E. C. Martin.

CUCURBITACEAE (Gourd Family)

Fig. 16. Cucumber. Cucumis sativus L. Coll. E. Lansing, MI. (Specimen not acetolysed as evident from plugged pores). Magnified 50x. About 100 microns. Spheroid. Exine echinate, spines 5 microns. Pores operculate. Picture made available by Dr. E. C. Martin.

COMPOSITAE (Composite Family)

Fig. 17. Goldenrod. Solidago spp. L. Coll. E. Lansing, MI (Specimen acetolysed). Magnified 2,000x. About 30 microns. Tricolporate. Baccharis type. Shape spheroidal. Spines 2.5 - 3.5 microns.

Fig. 18. New England Aster. Aster novae-angliae L. Coll. E. Lansing, MI. (Specimen acetolysed). Magnified 2,000x. About 30 microns. Tricolporate. Baccharis type. Shape spheroidal. Spines 2.5 - 3.5 microns long.

Fig. 19. Burdock. Arctium minus Schk. Coll. E. Lansing, MI (Specimen acetolysed). Magnified 2,000x. About 30 microns.

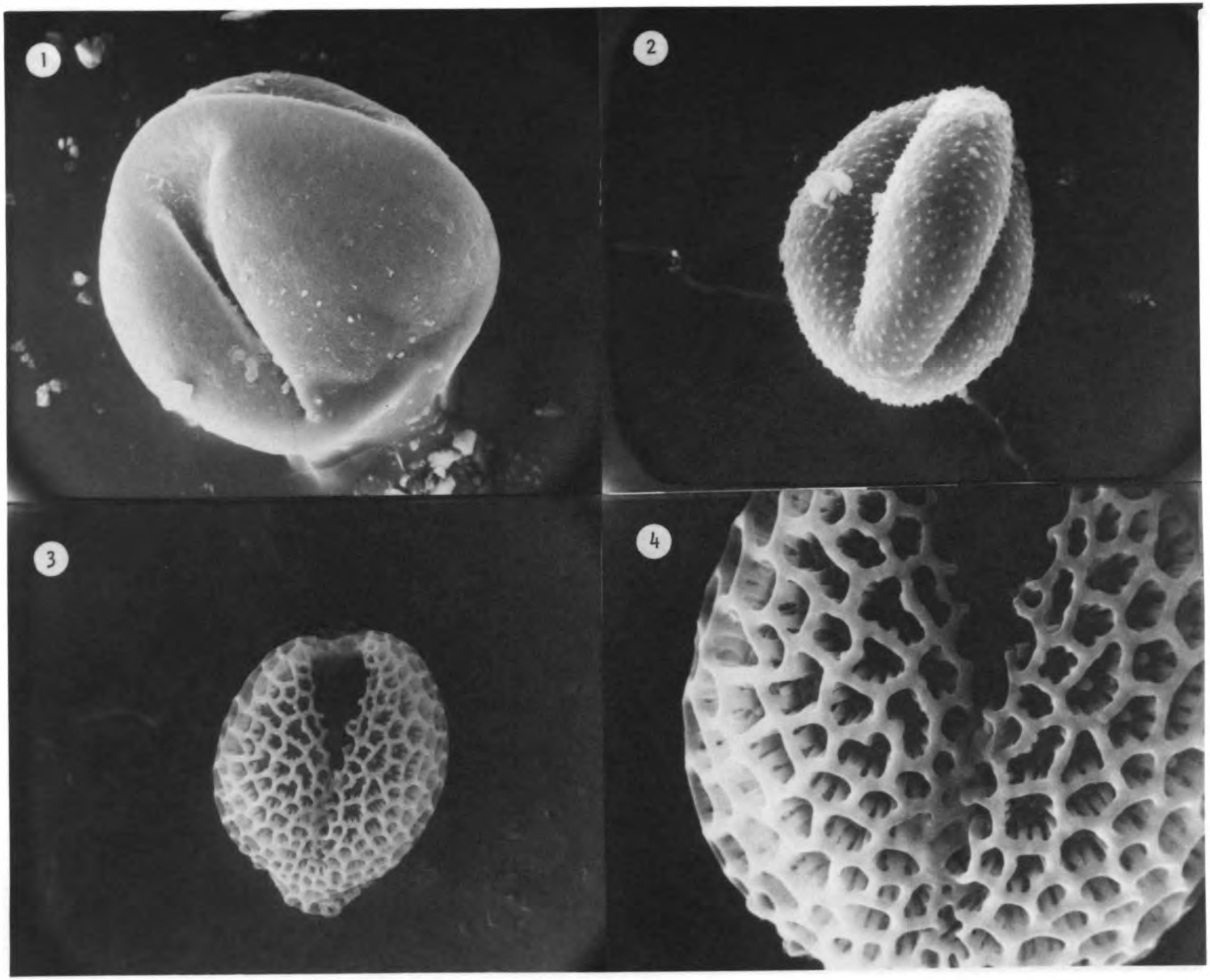
Fig. 20. Star Thistle or Spotted Knapweed. Centaurea maculosa Lam. Coll. Galesburg, MI. (Specimen acetolysed). Magnified 2,000x. About 27 microns. Tricolpate. Surface undulate, apparently vestigial spines. Nearly spheroidal. Furrow membrane smooth.

Fig. 21. Canada Thistle. Cirsium arvense (L.) Scop. Coll. E. Lansing, MI. (Specimen acetolysed). Magnified 2,000x. About 57 microns. Tricolporate. Thick exine with 4 - 5 micron spines. Spheroidal.

Fig. 22. Canada Thistle. Same pollen grain split open showing pollen grain wall layers.

Fig. 23. Dandelion. Taraxacum officinale Weber. Coll. E. Lansing, MI. (Specimen acetolysed). Magnified 2,000x. About 53 microns. Tricolporate. Eleven lacunae. Spheroidal.

Fig. 24. Chicory. Cichorium intybus L. Coll. E. Lansing, MI. (Specimen acetolysed). Magnified 2,000x. About 53 microns. Tricolporate. Eleven lacunae. Spheroidal.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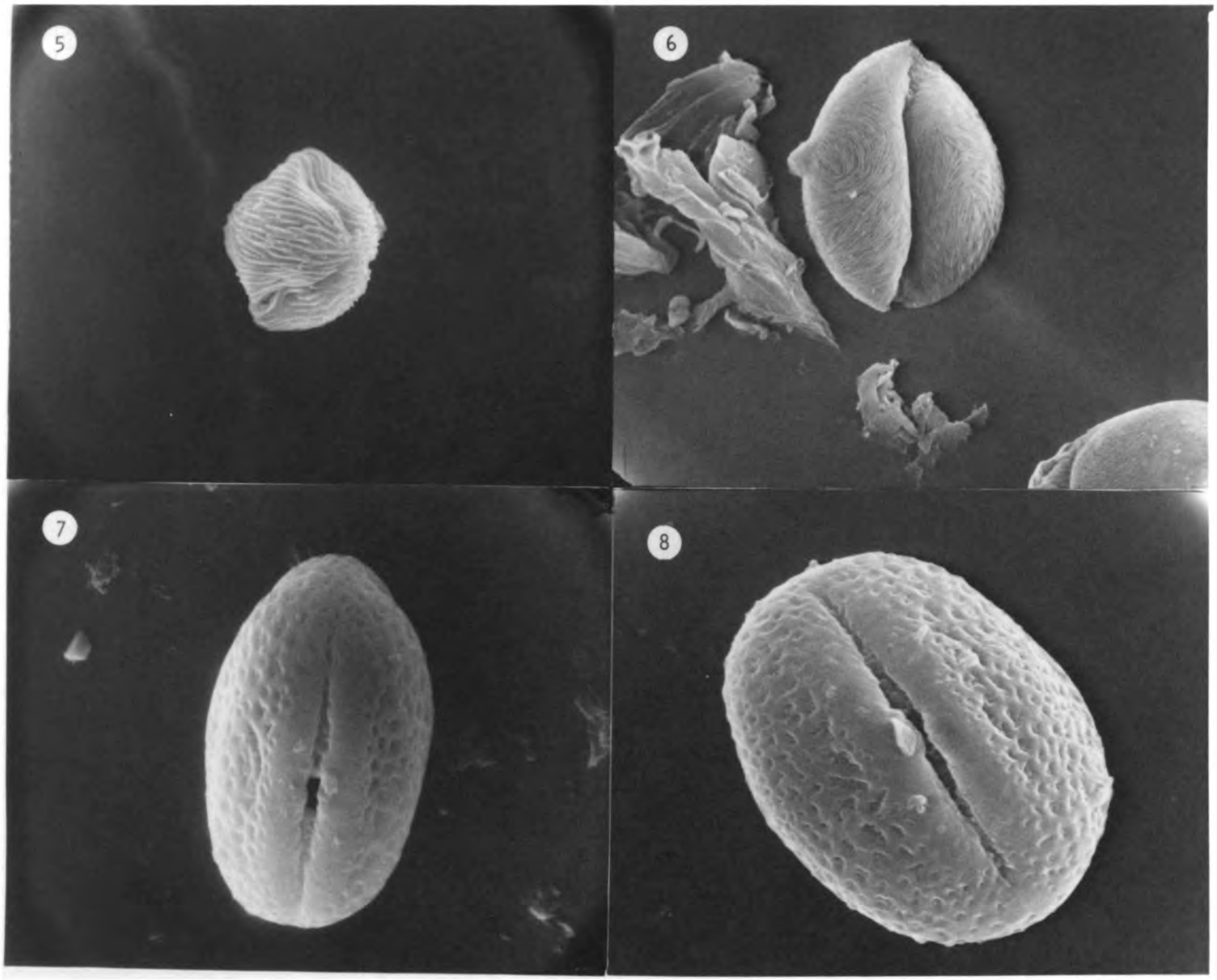
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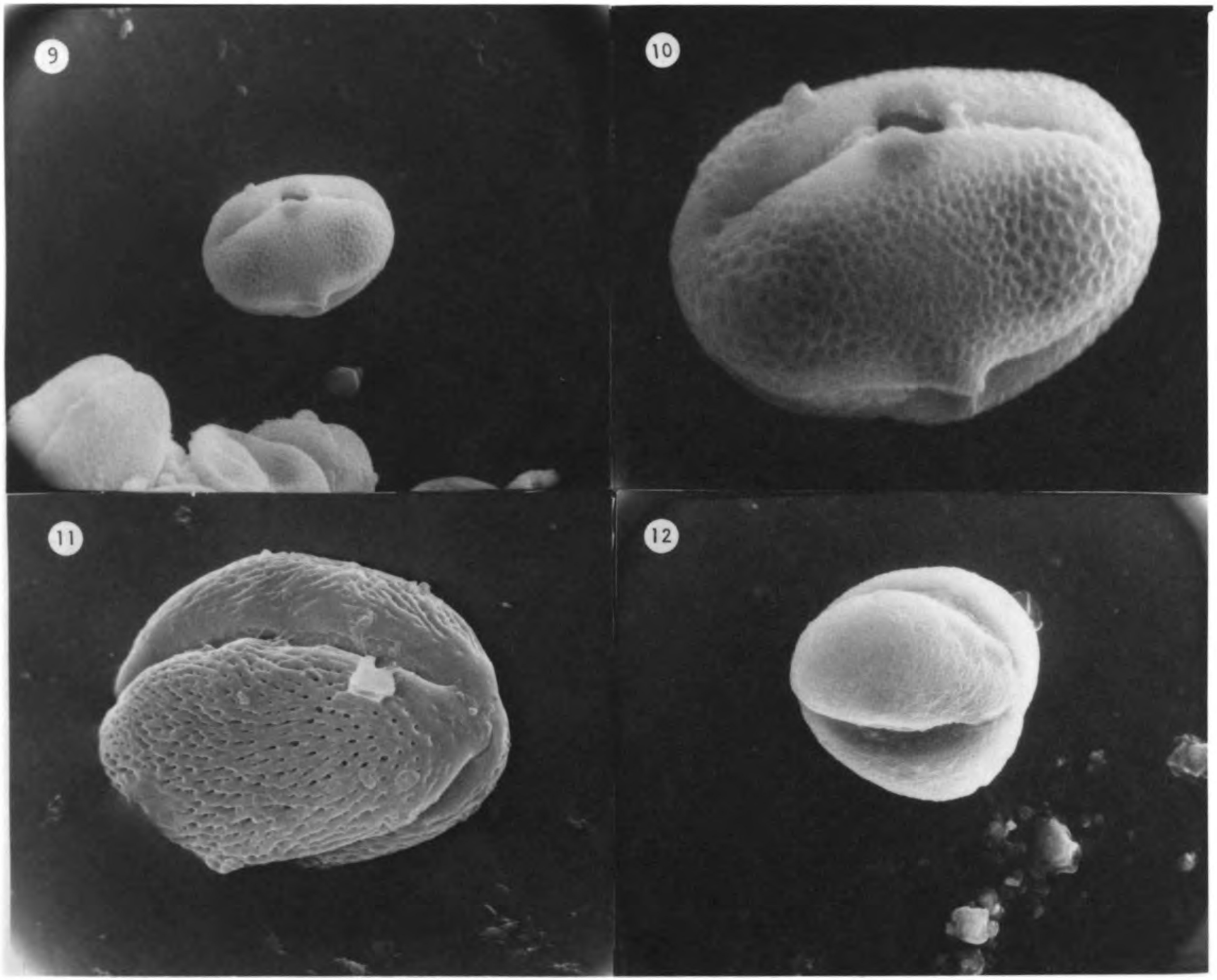
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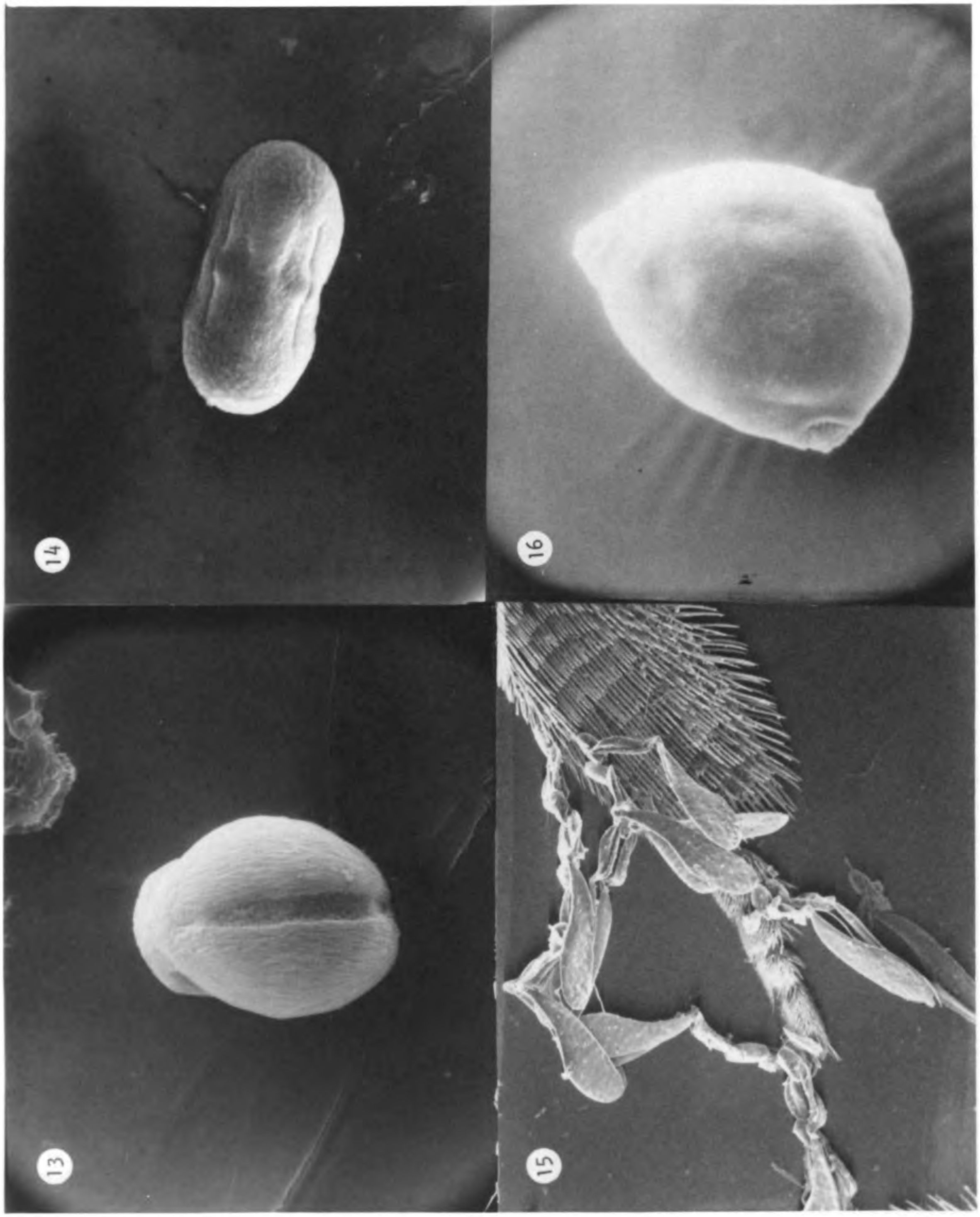
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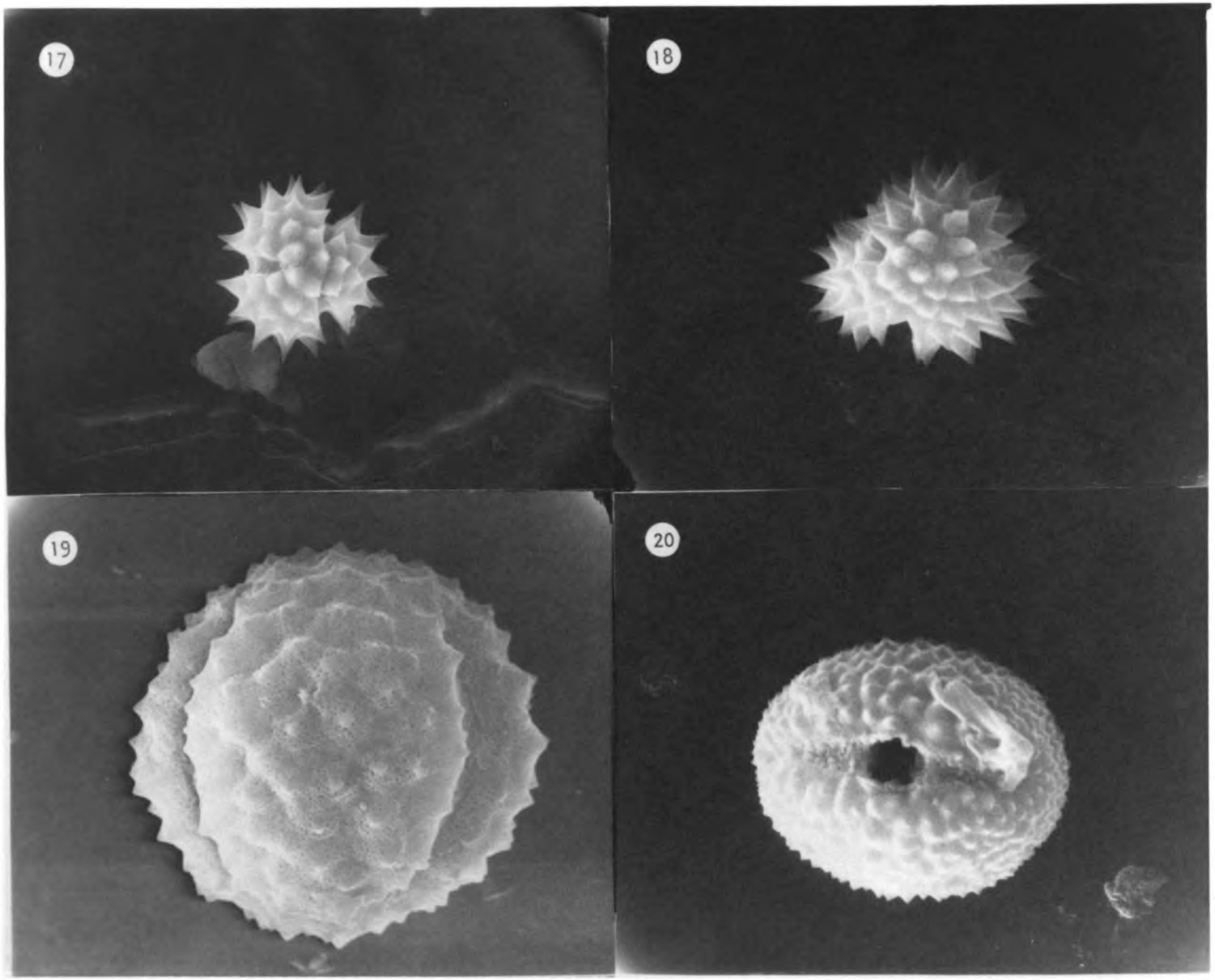
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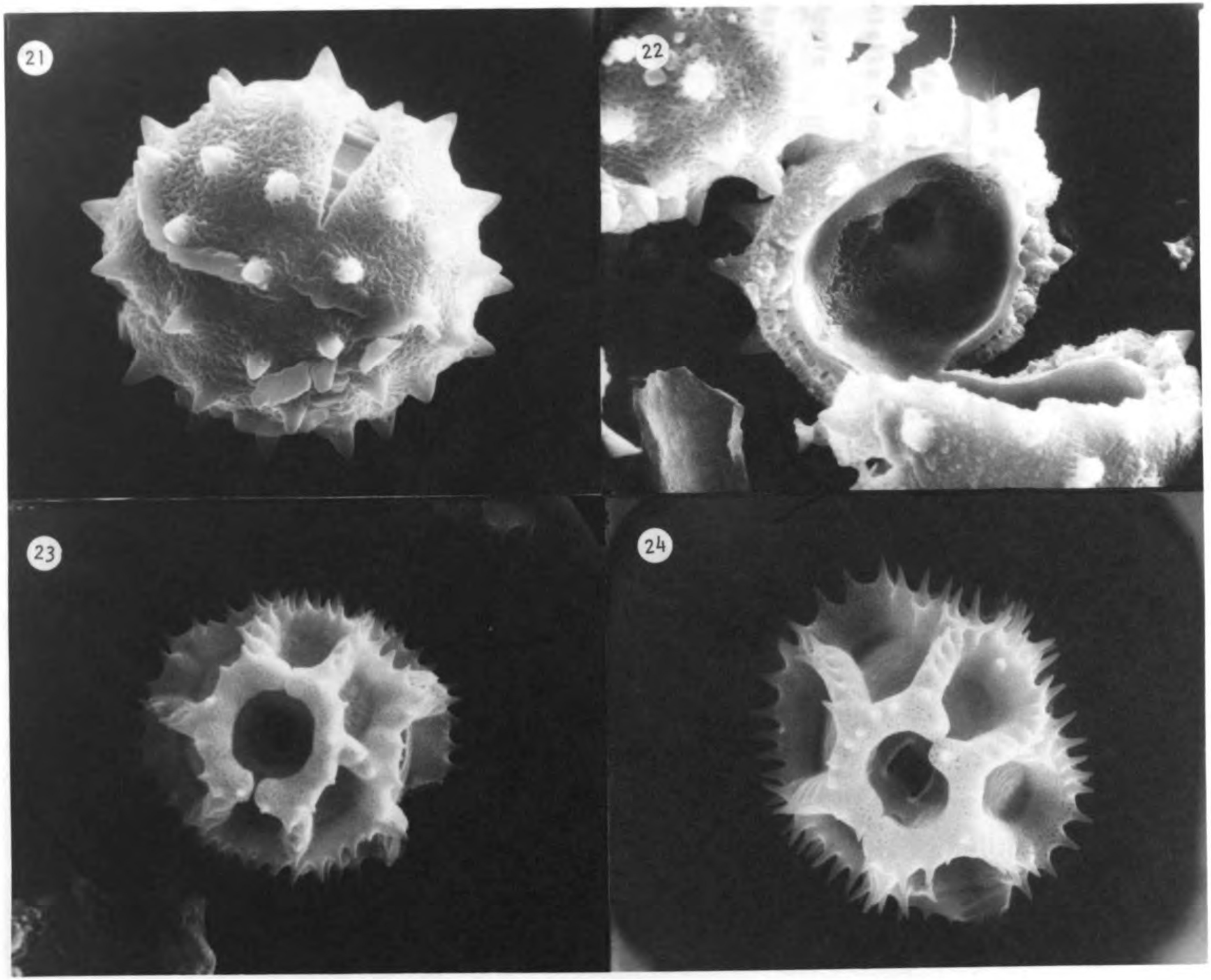
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APPENDIX II

LIST OF MICHIGAN POLLEN PLANTS

Common Name	Family Name	Generic Name
Alfalfa	Fabaceae	*Medicago sativa* L.
Alsike clover	Fabaceae	*Trifolium hybridum* L.
Apple	Rosaceae	*Pyrus malus* L.
Aster	Compositae	*Aster* spp. L.
Bird's-foot trefoil	Fabaceae	*Lotus corniculatus* L.
Black cherry	Rosaceae	*Prunus serotina* Ehrh.
Bloodroot	Papaveraceae	*Sanguinaria canadensis* L.
Blueberry	Ericaceae	*Vaccinium corymbosum* L.
Boxelder	Aceraceae	*Acer negundo* L.
Buckwheat	Polygonaceae	*Fagopyrum esculentum* Moench.
Bull Thistle	Compositae	*Cirsium vulgare* (Savi) Tenore.
Burdock	Compositae	*Arctium minus* Schk.
Canada Thistle	Compositae	*Cirsium arvense* (L.) Scop.
Charlock	Cruciferae	*Brassica kaber* (DC.) L. Wheeler.
Chicory	Compositae	*Cichorium intybus* L.
Cinquefoil	Rosaceae	*Potentilla* spp. L.
Corn	Gramineae	*Zea mays* L.
Crab Apple	Rosaceae	*Pyrus* spp. L.
Cucumber	Cucurbitaceae	*Cucumis sativus* L.
Dandelion	Compositae	*Taraxacum officinale* Weber.

Common Name	Family Name	Generic Name
Dog-tooth violet	Liliaceae	_Erythronium americanum_ Ker.
Elderberry	Caprifoliaceae	_Sambucus pubens_ Michx.
Goldenrod	Compositae	_Solidago_ spp. L.
Grape-hyacinth	Liliaceae	_Muscari botryoides_ (L.) Mill.
Gray dogwood	Cornaceae	_Cornus racemosa_ Lam.
Honeysuckle	Caprifoliaceae	_Lonicera_ spp. L.
Horse-chestnut	Hippocastanaceae	_Aesculus hippocastanum_ L.
Motherwort	Labiatae	_Leonurus cardiaca_ L.
Mustard	Cruciferae	_Brassica_ sp. L.
Narcissus	Amaryllidaceae	_Narcissus Pseudo-Narcissus_ L.
Pine	Pinaceae	_Pinus_ spp. L.
Plantain	Plantaginaceae	_Plantago_ spp. L.
Poison-ivy	Anacardiaceae	_Rhus radicans_ L.
Prickly Ash	Rutaceae	_Zanthoxylum americanum_ Mill.
Purple loosestrife	Lythraceae	_Lythrum salicaria_ L.
Queen Anne's lace	Umbelliferae	_Daucus carota_ L.
Ragweed	Compositae	_Ambrosia artemisiifolia_ L.
Red clover	Fabaceae	_Trifolium pratense_ L.
Silver maple	Aceraceae	_Acer saccharinum_ L.
Smartweed	Polygonaceae	_Polygonum_ spp. L.
Sow-thistle	Compositae	_Sonchus_ spp. L.
Spirea	Rosaceae	_Spiraea alba_ DuRoi.
Spring-beauty	Portulacaceae	_Claytonia virginica_ L.
Star-thistle	Compositae	_Centaurea maculosa_ Lam.
Strawberry	Rosaceae	_Fragaria virginiana_ hybrid Duchesne.

Common Name	Family Name	Generic Name
Sumac	Anacardiaceae	*Rhus* spp. L.
Sweet alyssum	Cruciferae	*Berteroa incana* (L.) DC.
Sweet cherry	Rosaceae	*Prunus avium* L.
Teasel	Dipsacaceae	*Dipsacus sylvestris* Huds.
Touch-me-not	Balsaminaceae	*Impatiens* spp. L.
Trillium	Liliaceae	*Trillium* spp. L.
White clover	Fabaceae	*Trifolium repens* L.
White sweet clover	Fabaceae	*Melilotus alba* Desr.
Willow	Salicaceae	*Salix* spp. L.
Yellow rocket	Cruciferae	*Barbarea vulgaris* R. Br.
Yellow sweet clover	Fabaceae	*Melilotus officinale* (L.) Desr.
Yew	Taxaceae	*Taxus canadensis* Marsh.