POLLEN WEIGHTS AND FORAGING ACTIVITIES OF THE HONEYBEE, APIS MELLIFERA

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POLLEN WEIGHTS AND FORAGING ACTIVITIES OF THE HONEYBEE, APIS MELLIFERA

An Abstract

Presented to

the Graduate Council of

Austin Peay State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Philip Francis Hertz

December 1971

ABSTRACT

Pollen weights of the honeybee (*Apis mellifera*) returning to the hive were measured to acquire an index basic to the pollen brought into the honeybee hive. Pollen weights were obtained from the last week of June to the second week in October 1971.

Pollen collection by honeybees on the Northwestern section of the Highland Rim is collected throughout the day but reaches a peak at approximately 1:00 PM Central Standard Time. The weather conditions in late July and early August influenced foraging and caused a decrease in pollen loads returned to the hive. The number of bees entering the trap was decreased during the month of August thus indicating that fewer bees were in the field during peak foraging times throughout the day. The last trap period in August showed an increase in pollen collection. The increase in pollen collection was evident until termination of the study which was caused by cold weather.

The mean weight of pollen for the entire study was 10.2 milligrams per foraging honeybee returning to the hive with pollen loads. The mean percentage of the pollen load per body weight was 10 percent with a range of 0 to 35 percent.

Bright clear days allowed greater foraging and greater pollen collections. Bees seem to prefer the brighter colored pollen to the darker colored pollens. When the brighter colored pollens were collected, the mean pollen weight was

heavier.

Results of behavioral tests with honeybees in an isolated condition suggested that lowered temperatures for extended periods altered the normal reactions of the honeybee which resulted in either limited movement or death.

POLLEN WEIGHTS AND FORAGING ACTIVITIES OF THE HONEYBEE, *APIS MELLIFERA*

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Master of Science

by

Philip Francis Hertz

December 1971

To the Graduate Council:

I am submitting herewith a Thesis written by Philip Francis Hertz entitled "Pollen Weights and Foraging Activities of the Honeybee, *Apis mellifera*." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Biology.

Floyd M. Ford
Major Professor

We have read this thesis and recommend its acceptance:

Marvin M. Droer
Second Committee Member

Benj. P. Stone
Third Committee Member

Accepted for the Council:

Wayne E. Stamper
Dean of the Graduate School

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The honeybee (*Apis mellifera*) is generally regarded as one of the most important pollinators in the United States (Root 1966). Although several other species of insects are considered as pollinators and pollen collectors. Pollen is a necessity for flower reproduction as well as a food source for honeybee brood rearing and colony maintenance. Variables such as weather, seasons, abundance of flowers, location and the foragers involved in collecting pollen play significant roles in pollen collection. Taking all of the mentioned variables into consideration, an estimation can be made as to the amount of pollen carried by individual honeybees.

The bumble bee (*Bombus sp.*) is considered second to the honeybee as a major pollen consumer. When the honeybee's foraging activity was at its greatest, the bumble bee activity was at its lowest (Holmes 1964). Competition therefore was of little importance to the foraging honeybee. Weather, on the other hand, greatly influences the foraging activity of the honeybee as well as the pollen loads being returned to the hive (Root 1966).

Geographically, Montgomery county, Tennessee is located in an important physiographical region, the Highland Rim. Peak performance periods in pollen collection were determined for this location as well as the peak in time of collections.

The objectives of this study were to determine: 1) the mean body weights of pollen and non-pollen carriers; 2) the time of day when pollen collection is greatest on the Northwestern section of the Highland Rim; 3) the time when honeybees are foraging heaviest; 4) pollen collection as influenced by weather conditions; and 5) the mean weight of pollen per individual honeybee.

CHAPTER II

LITERATURE REVIEW

Apis mellifera, the honeybee is one of the most studied insects today and has been since 15000 B.C. The apicultural interest in the constitution of pollen is: the chief source of protein, minerals and special biological products in the honeybee diet, and its part in the determination of the brood-rearing cycle (Root 1966).

Todd and Bretherick (1942) stated that air dried pollen collected by bees had a water content of 7.01 to 16.23 percent, with a mean of 11.16 percent. Water thus makes up a large but variable part of pollen.

Protein is the most important constituent of pollen from the standpoint of the honeybee colony. Analyses by Todd and Bretherick (1942) shows that bee-collected pollens have a wide range in protein values 7.02 to 29.87 percent, with a mean of 21.60 percent. Pollens also contain fats (1.50 to 23.60 percent), ash (2.80 to 10.60 percent) and sugar values, but most pollen are low in starch (0.8 to 11 percent).

Hodges (1967) showed that the single hair in the floor of the corbicula is necessary for carrying pollen on the worker bee leg. A hair was removed from the left leg, while the hair on the right leg of the worker bee remained intact. These marked bees returned to the hive and were trapped. The hair shaft in the corbicula is relative to the amount of pollen carried by individual bees since the load on the left leg was significantly smaller than the right leg. Parker (1926) stated that the single hair is utilized as a pin through the middle of the load to act as a stabilizer on the leg. Jay (1969) removed different legs on the worker bee. This in turn affected the pollen loads carried. His results showed that after the right front leg had been removed, usually one or other cobicula held only a small amount of pollen. When pollen was observed in both corbicula the left one held the larger amount. After the right middle leg was removed, pollen was found either in trace amounts in both corbiculae or in small amounts in the left leg only. However, leg removal did not effect nectar collections. He concluded that it is doubtful whether leg amputation affected the pollen collectors' attempts to collect pollen on their next trip, because nectar gatherers with one leg amputated collected nectar in large amounts on their first trip after amputation. Pollen collecting bees whose hind leg had been removed gradually switched to nectar collecting. This could have been due to the failure of the crop they were working.

The amount of pollen carried varies with location, time of year, time of day, climatic conditions, age of individual bees, and age of the colony (Root 1966). Fukuda, Moriya, and Sekiguchi (1969) found that the mean weight of crop contents of 640 pollen faragers is 15.0 mg. Apparently the load is less than in the case of nectar foragers and those with a nearly empty crop constitute a considerable proportion. He further demonstrated that numerous pollen foragers have a crop content nearly equal to the maximum crop weight in nectar foragers. This fact suggests the occurance of foragers which practice both pollen and nectar foragings in one and the same trip.

Jaycox (1970a) found that foraging bees select the more attractive and productive flowers from among those available at the same time. Percival (1947) showed that pollen is collected in greatest quantity from the bees' main nectar source. Jaycox (1970a) examined bees foraging on soybeans and found that 55 to 100 percent of the bees were carrying some pollen on their legs, during daily samples.

Temperature is one variable that is considered to greatly influence the collection of nectar and pollen. Warm days and cool nights seem to be ideal for weight gains within the colony (Jaycox 1970a). Moffett and Parker (1953) found that 79 percent of the colony's weight gain in July and August took place when maximum temperatures reached 85 to 99 degrees Fahrenheit. In 1944, Johnson reported heavy weight gains in the colony during July and August when temperatures reached 80 to 100 degrees F. Jaycox (1970a) in his study on soybeans found that gains in weight were greater when temperatures were 80 degrees F. or above. Temperature can speed up or slow down the metabolism of the honeybee.

Jaycox (1970b) found that bees were active in the field from 8:00 AM to about 4:00 PM Central Standard Time. He showed that foraging was greatest during the midday hours and declined steadily to 4:00 PM when foraging was almost nil. Increased foraging at midday was attributed to an interaction involving temperature, moisture, plants and bees.

Pellett (1947), as stated by Jaycox (1970b) reported that bees were active from 9:00 AM until sunset in Tennessee and from early morning until noon or 1:00 PM in North Carolina. The differences could easily be the result of local conditions or limited observation. Jay (1969) showed that honeybees collected pollen in large amounts and foraged heaviest from 1:00 PM to 4:00 PM during the month of August. The cause could be attributed to the difference in geographical locations, local conditions or as suggested by Jaycox (1970b) limited observations.

Pollen collection takes place throughout the day if weather conditions permit (Percival 1947). She observed that the rhythm of pollen collection during the day is a curve with maximum values between 12 noon and 1:30 PM GMT and that after 5:30 PM the curve falls rapidly to zero. Holmes (1964) recorded that honeybee numbers increased progressively during early afternoon hours and diminished steadily during late afternoon.

Casteel (1912) found that bees were little affected by the loss of their pollen loads in later foraging activities. McDonald (1967) observed that even though the pollen loads were emptied at the entrance to the hive the honeybees went on to seek out a cell and go through the pollen-depositing activity as if they still carried pollen loads. Free (1953) found that removing pollen loads from bees decreased their tendency to collect pollen.

Behavior of the honeybee is easily affected when the bees' activity departs from the normal. Weather is an important influence in honeybee behavior while man is probably the other greatest factor causing a variation in the temperament of the honeybee (Root 1966). The honeybee colony is a social organization and as such is subject to some demoralization when it is disturbed (Taber 1963).

Smoke has been used for a number of years by apiculturists to calm bees. Newton (1968) showed that smoke causes engorging behavior by honeybees in which they fill the honeysac with cured honey. Free (1968) conducted a similar study and obtained similar results. No literature could be found concerning the effects of temperature on honeybees in an isolated condition.

CHAPTER III

METHODS AND MATERIALS

Live Trapping Methods

Two different types of hives were used during the study. The standard wood box hive consisting of 10 Langstroth frames per unit with 2 sections of brood chambers and at least 2 sections of shallow supers. The brood chambers were 24.10 cm deep by 50.80cm long by 43.10cm wide. The standard wood box hive was estimated to contain not less than 20,000 honeybees and probably not more than 60,000.

The wood trap that was inserted into the original opening of the standard hive measured 39.40cm long by 13.90cm wide by 1.90cm deep. The trap was inserted into the original opening of the standard hive at least 2 days before the trapping period began. The portion of the original entrance to the hive not enclosed by the trap was shut off by a wood strip to insure that the bees would use the trap. A wood plunger the size of the inside of the trap was utilized to stop the bees from entering the trap from the inside of the hive and to ensure that only foraging bees would be in the trap during the collection periods.

Two minute waiting periods were allowed from the time of the insertion of the wood plunger into the trap until the time the trap was closed from the outside by a plastic collecting container. After the plastic container was connected with the trap the plunger was removed and bees were forced into the plastic container. The plastic collecting container was then sealed and taken to the laboratory and placed in a cold room at 2 degrees Centigrade.

The second type of hive used in the test was the observation hive which measured 53.30cm long by 8.90cm wide by 50.80cm deep. A 6.40cm hole was drilled on top of each hive to allow a place for the attachment of an aluminum entrance pipe which was utilized to trap the bees. The same trapping technique was employed with this hive as the standard wood box hive.

Laboratory Measurements

The honeybees were allowed to remain in the cold room which maintained an average 2 degree Centigrade. It was previously determined that the activity range of the *Apis mellifera* was 10 degrees Centigrade to 35 degrees Centigrade (Spencer 1956). By utilizing this chilling technique, none of the bees had to be sacrificed for the test. After 2 hours of cold treatment, the bees were separated into groups of pollen and non-pollen carriers while still in the cold room. A random sampling of 20 bees per grouping was made. The pollen carrying bees had their pollen removed and kept in alignment with each bee body.

Weighing was completed on a Mettler Gram Atic balance and weights were measured to the nearest 1000 of a gram. Honeybees were weighed immediately after removal from the cold room. After approximately 20 minutes the bees became active and within 1 hour they were totally active. The 20 minute period allowed enough time to weigh all 20 bees on an individual basis. All bees were returned to the entrance of the hive and no fatality was observed in any of the returned bees.

Pollen was also weighed on an individual basis and recorded against the body weight of the carrying bee. Color of individual pollen pellets was also recorded but no assay was made to determine the source of the pollen. Pollen was placed into light and dark categories. Pollen pellets were removed from the legs of the bees with a probe and forceps. Pollen pellets were weighed immediately upon removal from the cold room.

Collections were made at 3 different times throughout the day during the month of July 1971 to determine which time of day honeybees would be foraging heaviest and which time they would be returning with the heaviest loads of pollen at this location on the Highland Rim.

The observation hives were used to conduct the behavior portion of the study. One brood chamber without brood was placed in the observation hive and then placed in the cold room at 2 degrees Centigrade and allowed to remain there for 4 hours. Bees were then removed and allowed to warm at room temperature. Observations of all activities were recorded during the recovery period at room temperature.

One monthly collection was made at the beginning of the study (month of July) then two 6 day studies per month usually on alternate weeks within the month. All times were Central Daylight Savings Time (CDT). All collections were made within $\pm$15 minutes of the collection time.

The bee yard was on the campus of Austin Peay State University, Montgomery County, Clarksville, Tennessee. All hives were kept in one area where each hive had approximately an equal amount of sunshine and shade.

Worker bees were supplied by local beekeepers and queen bees were ordered from the Walter T. Kelley Company, Clarkson, Kentucky.

Weather information for the test period was obtained from the United States Air Force Weather Detachment located at Fort Campbell, Kentucky.

Cloud cover or sky conditions are recorded in four basic ways by the United States Air Force weather stations: 1) Clear, 2)Broken, 3)Scattered, and 4) Overcast with each having a certain formula to designate the amount within each category. The four categories are used to indicate the weather conditions on collection days. The term "Clear" represents days that are sunny with high temperatures (above 26 degrees Centigrade). "Broken" refers to conditions in which some clouds are present that do not affect sunshine or brightness of day to any great extent, and for all practical purposes it is considered on the same basis as a clear day. "Scattered" indicates the presence of several clouds with intermittent sunshine although the day remains relatively bright. "Overcast" is a complete blocking out of sunshine. This grouping includes hazy days, cloudy days, and rainy days.

Terminology

Pollen carriers - bees returning from the field with pollen loads on their legs.

Non-pollen carriers - bees returning from the field without pollen loads on their legs. In this group, the inclusion of some younger bees which still had not started their foraging duty is possible.

CHAPTER IV

RESULTS

Foraging Activity

A total of 8,976 bees were captured throughout the study period which was conducted from June 29, 1971 to October 2, 1971. No measures were taken to prevent recaptures. The possibility of the same individual bee being retrapped several times did exist. A test was employed to determine the time of day when bees were carrying the heaviest pollen loads. Samples were taken three times daily during the month of July as shown in Figure 1. This figure illustrates the mean body weights throughout the month and also the mean pollen weights. The three times utilized were 10:30AM, 2:00PM and 6:00PM CDT. The 6:00PM catch was eliminated since a high number of bees were returning to the hive without pollen or the pollen loads were smaller than the other 2 collection periods.

No significant difference appeared between the 10:30AM and 2:00PM collections when considering the mean pollen weight per bee per day. However, the 2:00PM collection had the highest percentage (74%) of bees in the field as as compared to the 10:30AM collections (63%). Again the 2:00PM collection had a greater percentage of bees returning to the hive with pollen when compared to the 10:30AM

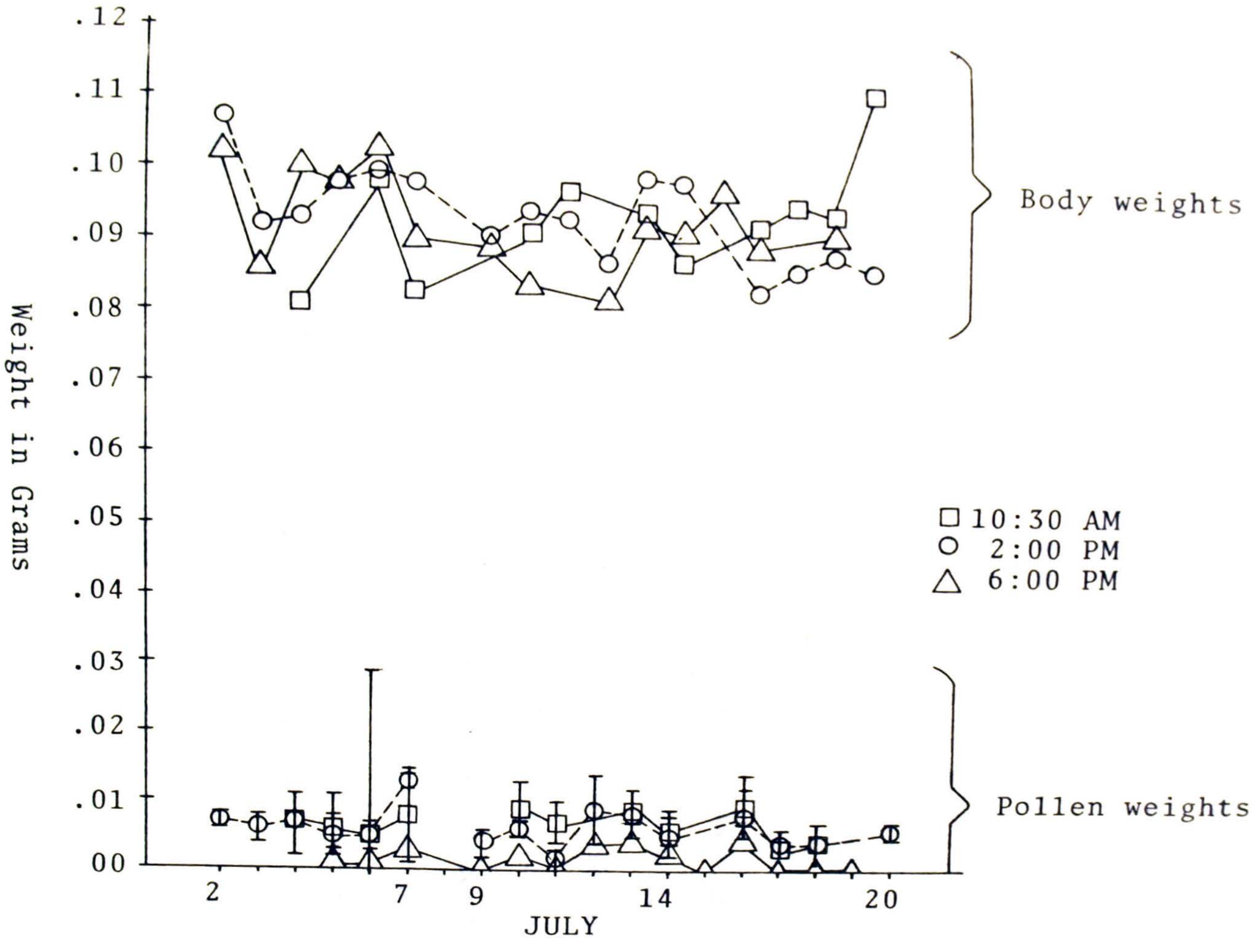

FIGURE 1. Mean body and pollen weights of honeybees during the month of July 1971.

collection. Similar results were shown by Holmes (1964), Jay (1969), Jaycox (1970a&b), Pellett (1949), and Percival (1949). Although all these authors except Pellett(1949) shows a rapid decrease in foraging in late afternoon, this decline may be due to location. He found that bees forage until dusk in Tennessee. This location on the Highland Rim agrees more with Pellett's results. The bees were observed foraging until sunset even though the loads of pollen were definitely smaller in the latter part of the day. The peak of foraging activity is during the mid-day hour.

Figure 2 gives a daily account of the 2:00 PM CDT collections throughout the study including the average daily body weights and average daily pollen weights. On a mean basis the body weights throughout the study did not differ greatly. Wells and Giacchine (1968) stated that nectar carriers can carry loads of nectar up to 90 percent of their body weights depending on the size of the bee and size of the honey-sac. In effect they are saying the heavier bees are carrying the heavier loads of nectar. Although this could not be determined in the results conducted in this survey it was evident that body weights varied a great deal among individual honeybees indicating that a variation of nectar was being carried.

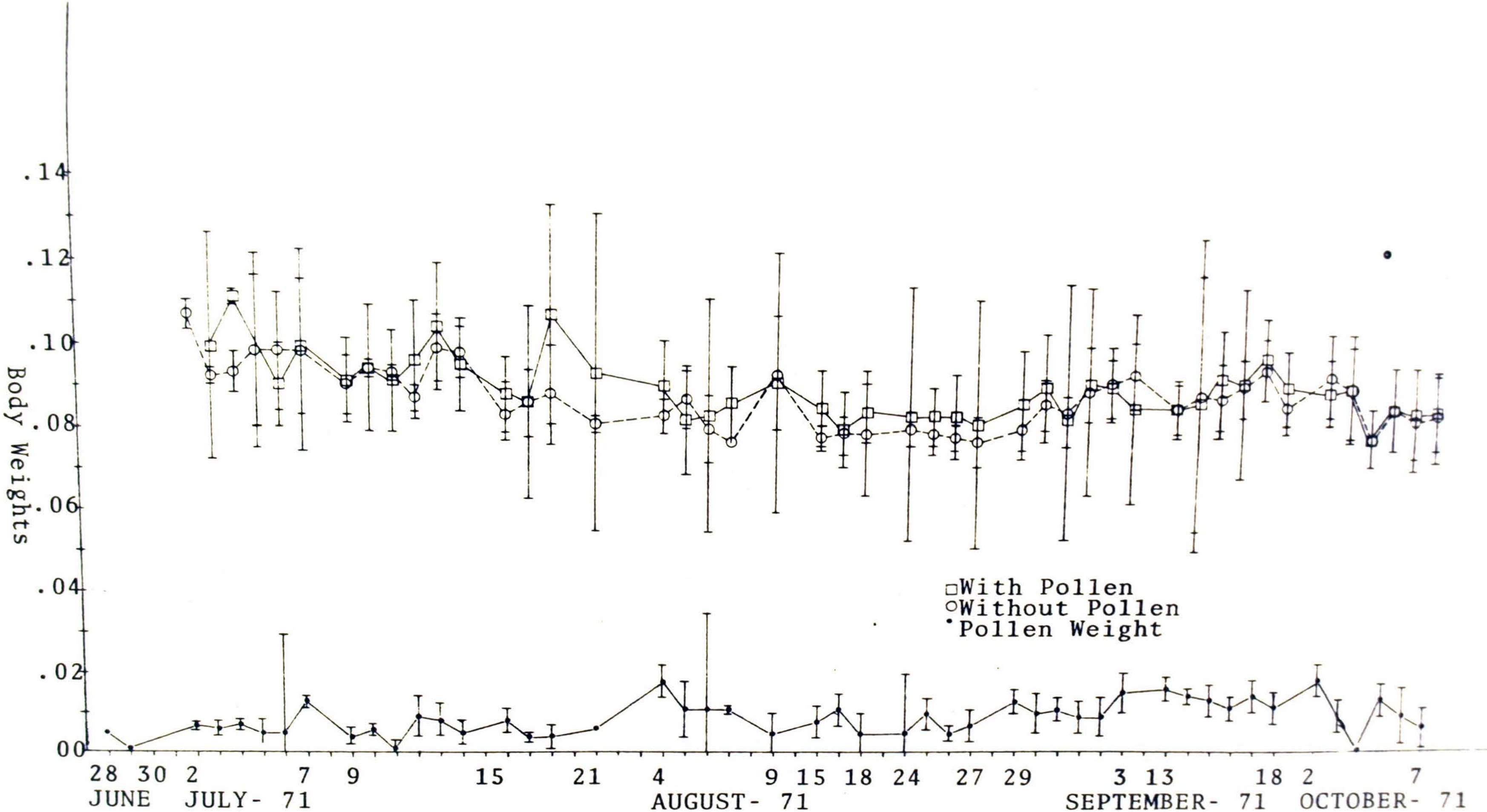

FIGURE 2. Mean body weights of honeybees at 2:00PM and the amount of pollen carried.

Weather

Table I shows the weather a day before the weekly trap period, the trap days themselves, and the day after the weekly trap period. The effect of weather conditions on the collection of pollen is primarily a manifestation of the influence of weather on the activity of the flying bee as a whole (Percival 1949).

Foraging was greatest when the temperature was above 26 degrees C. and the cloud cover ranged from clear to scattered. Increased pollen collection by the honeybee on warm, clear days may be attributed to the fact that flowers were open and available to the bees. Tripping of the anthers to release pollen grains by the honeybee may have been easier when the prevailing weather was clear, warm, and sunny. Cloud cover considered as scattered seemed to have no effect on pollen collection. These days were usually bright, clouds were usually high in the sky and temperatures were above 26 degrees C.

Overcast weather resulted in a smaller percentage of bees foraging during this type of weather. The percentage of bees foraging and returning with pollen during overcast days seldom rose above 30 percent as shown in Figure 3. Heavily overcast days usually resulted in lower temperatures, rain, and lower amounts of pollen collected (Fig. 3).. On two different occasions throughout the study (July 9 and 11) the honeybees collected pollen above the 30% level during overcast sky conditions as shown in Table 1 and Figure 3.

TABLE I.1 WEATHER CONDITIONS ON COLLECTION DAYS, DAYS PRECEDING AND FOLLOWING COLLECTION DAYS FOR THE MONTH OF JULY.

Date	Temp. degrees Centigrade MAX.	MIN.	MEAN	2PM	Precip. in Inches	Wind Velocity (mph)	Cloud Cover
July 1*	29.5	21	26.5	29.5	.15	08	Clear-Scat.
2	28	26.5	27	28	00	08	Clear-Over.
3	29	16.5	22.5	28.5	00	02	Clear-Scat.
4	29.5	20	25	29.5	00	08	Overcast
5	30	20.5	25.5	28.5	00	08	Clear-Scat.
6	30	17	24	28.5	.39	02	Scattered
7	30	23.5	26.5	29	00	03	Clear-Scat.
8*	32	21.5	27	31.5	00	08	Clear-Scat.
9	33.5	19	26.5	33.5	00	01	Overcast
10	33.5	21.5	28	33.5	00	08	Clear
11	29.5	20	25	28.5	.69	04	Overcast
12	29	21	25	28.5	00	03	Clear
13	32	19.5	26	30.5	.25	06	Overcast
14	26	21.5	24	26	.04	05	Overcast
15*	24	19	21.5	20	.73	16	Overcast
16	28.5	15.5	22	28	00	00	Clear
17	30	19.5	25	30	00	06	Clear
18	29.5	26	27	29.5	00	11	Overcast
19	28	20.5	24.5	26.5	.10	12	Overcast
20	24	19	21.5	24	00	08	Scattered

*Day before and day after

TABLE I.2 WEATHER CONDITIONS ON COLLECTION DAYS, DAYS PRECEDING AND FOLLOWING COLLECTION DAYS FOR THE MONTH OF AUGUST.

Date	Temp. degrees Centigrade				Precip. in Inches	Wind Velocity	Cloud Cover
	MAX.	MIN.	MEAN	2PM			
August 3*	24.5	21	23	21.5	2.57	04	Overcast
4	27	21.5	24.5	27	.21	06	Scattered
5	26	21.5	23.5	25.5	.94	00	Clear
6	26.5	23.5	25	26	00	04	Overcast
7	27.5	24	26.5	27	00	05	Scattered
8*	29.5	21	25.5	29.5	00	02	Clear
9	31.5	22.5	27	31.5	.41	01	Scattered
10	29.5	22.5	26	29.5	.99	00	Scattered
17	30	25	27.5	29	00	08	Clear
18	27.5	24	26	27	00	05	Scattered
19	31.5	25	28.5	31.5	00	06	Clear
20	30.5	25	27.5	30.5	00	06	Clear
21	30	25.5	27.5	29	.73	08	Overcast
22	24.5	21	22.5	22	.70	03	Overcast
23	29	22.5	25.5	27.5	00	03	Clear
24	31	23.5	27.5	30	00	06	Scattered
25	31	24	27.5	30	00	06	Clear
26	28.5	21.5	25	24	.67	06	Clear-Over.
27	24.5	18	21	24.5	00	09	Clear
28*	25.5	18	21.5	25.5	00	04	Clear
29	22.5	25	26.5	22.5	00	06	Clear

TABLE I.2 (continued)

30	29	25	27.5	28.5	00	06	Clear
31	28.5	23.5	26	28.5	.61	04	Scattered

*Day before and day after

TABLE I.3 WEATHER CONDITIONS ON COLLECTION DAYS, DAYS PRECEDING AND FOLLOWING COLLECTION DAYS FOR THE MONTH OF SEPTEMBER.

Date	Temp. degrees Centigrade				Precip. in Inches	Wind Velocity	Cloud Cover
	MAX.	MIN.	MEAN	2PM			
September							
1	27	21.5	24.5	27	.87	04	Scattered
2	27	22.5	25	27	.06	10	Clear-Scat.
3	26.5	21	24	26.5	.85	06	Clear-Scat.
4*	30	20.5	25	30	00	00	Clear-Scat.
12*	24.5	17.5	20.5	24.5	00	11	Clear-Scat.
13	27	16.5	21.5	27	00	07	Clear
14	31	18.5	25	31	00	07	Clear
15	29.5	18.5	24	29.5	.01	04	Scattered
16	24	16.5	20	24	00	00	Clear-Scat
17	26	17.5	21.5	26	00	06	Scattered
18	23.5	17.5	20.5	23.5	00	07	Overcast
19*	25.5	21	23.5	25.5	T	03	Overcast

*Day before and day after

TABLE I.4 WEATHER CONDITIONS ON COLLECTION DAYS, DAYS PRECEDING AND FOLLOWING COLLECTION DAYS FOR THE MONTH OF OCTOBER.

Date	Temp. degrees Centigrade				Precip. in Inches	Wind Velocity	Cloud Cover
	MAX.	MIN.	MEAN	2PM			
October							
1*	29.5	19	24	29.5	00	04	Clear
2	24	20	21.5	24	00	10	Clear
3	19.5	13	16	19.5	00	04	Clear
4	24	18	20.5	24	.86	00	Overcast
5	24	18	20.5	24	00	02	Overcast
6	24	16.5	20	24	00	10	Clear
7	19.5	10.5	15	19.5	00	04	Clear
8*	21.5	10.5	16.5	21.5	T	12	Overcast

*Day before and day after

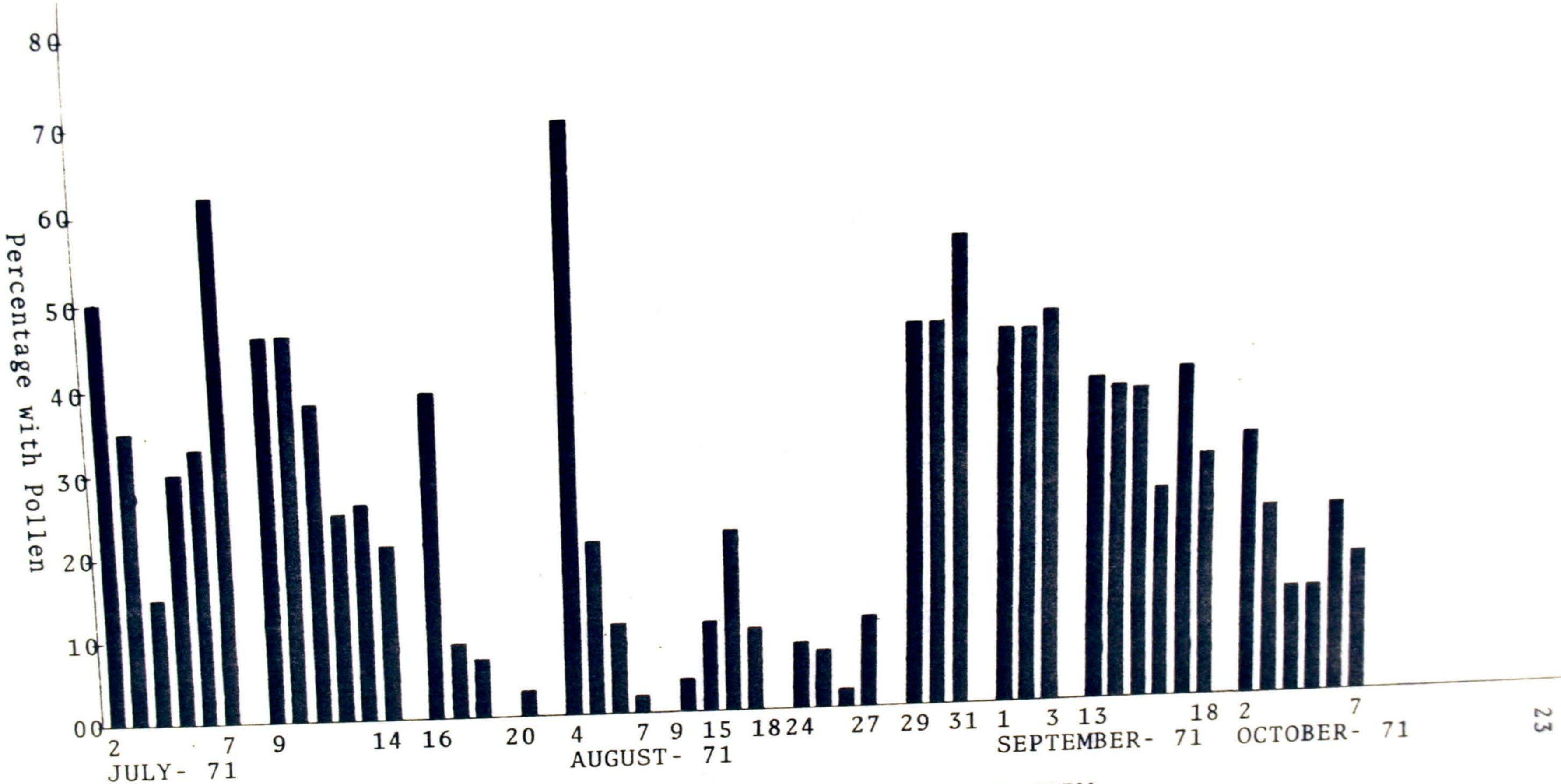

FIGURE 3. Bees foraging and returning with pollen at 2:00PM.

On both days temperatures were very high (above 29 degrees C.) which could account for pollen collections to nearly equal the pollen collections on clear days. Table II is an indicator of the results as partially discussed above. The comparisons shown in this table indicate that the mean is not significantly different in the clear, clear to scattered, and scattered skies but a difference does occur when each of the above mentioned means is compared with the overcast sky. The student t test was employed to determine the confidence level. Significant difference was then determined based on the 95 percent confidence level.

Collections made during rain showed that very little or no pollen was collected. No bright colored pollen was collected during the rain.

A decrease in collection is evident (Fig. 3) beginning with the 17th of July and ending the 27th of August. The period of July 17 through July 20 encountered a great deal of environmental influences. During this period the observation hives were exposed to high winds and heavy rain at night. On two occasions, the high winds blew the observation hives over and broke the glass which allowed combs to become drenched with rain water. Secondly, during this period, intruders harrassed the hives continuously and 3 of the 5 hives eventually resulted in swarming. These events undoubtedly resulted in the lower readings during that time period of the test.

Precipitation in the form of rain definitely hampered

TABLE II. INFLUENCES OF CLOUD COVER ON POLLEN WEIGHTS.*

Cloud Cover	Mean Pollen Weight (mg)	Standard Deviation	Number Sample Days	Degrees Freedom	Confidence Level	Significant Difference
Clear	9.6	3.2	15			
Clear-Scat.	9.5	3.9	6			
Scattered	9.2	5.7	11			
Overcast	6.3	4.1	9			
<u>Comparisons</u>:						
Clear to Scat.	9.6/9.2		15/11	24	10%	No
Clear to Clear-Scat.	9.6/9.5		15/6	9	10%	No
Clear to Over.	9.6/6.3		15/9	22	99+%	Yes
Clear-Scat. to Overcast	9.5/6.3		9/6	13	99+%	Yes
Scat. to Over.	9.2/6.3		11/9	18	99+%	Yes

*student t test

collections of pollen. Collections during heavy rain revealed that the bees were remaining in the hive and not foraging. Rain, the day previous to collections, seemed to have no effect if the following day had high temperatures and sky conditions were clear to scattered. An exception is the month of August when the flowers were not available. Rainy days followed by days with overcast skies resulted in a smaller amount of bees returning to the hive with pollen loads as well as fewer bees foraging in the field.

Wind on clear days with high temperatures did not indicate an effect on pollen collections. However, wind accompanied by overcast skies prevented pollen collection and foraging. Wind and rain completely stopped foraging. Only 6 times throughout the test did the winds rise above 10mph velocity. On all 6 occasions the daily mean temperature was below 26 degrees C. and collections were smaller than normal for days of similar conditions without wind. The highest wind reading was 16mph, however, this occured during the week of July 15-20 when storms and rain were prevalent in this area. High winds on one day followed by calm days the next did not appear to have an effect on pollen collections on the calm days.

As temperatures decreased during the month of October, the bees foraged less. Very few bees were observed to leave the hive when temperatures dropped below 15 degrees C.

Pollen Collections

Pollen collections take place throughout the day if weather conditions permit. The greatest amount of pollen is collected at the time at which the major nectar crops are in flower, and that peak days in pollen collection coincide with peaks in the flowering of major crops (Percival 1947). Figure 3 seems to bear this point out as there is a definite slack period in flowering during the month of August. Personal communication with commercial beekeepers reported that this has been observed in their bee yards for a number of years. This lag phase is evidently a time between the flowering periods. Most of the summer flowers have completed their flowering cycle and the last group of flowers in the early fall have not yet come into bloom thus resulting in the little or no collecting by the honeybees. Bees do not forage as heavily during this time and the percentage of bees returning to the hive is quite low when compared to the normal flowering cycle.

Figure 4 illustrates the mean pollen weight per trap period. The heaviest pollen weights were obtained simply by going through the recorded data and picking out the heaviest pollen weight collected per day and then getting the mean for the trap period. The lightest weight pollens were obtained in the same manner. Average pollen weights were determined by the total pollen collected for the day then obtaining a mean for the trap period.

Although various factors influence the amount of pollen

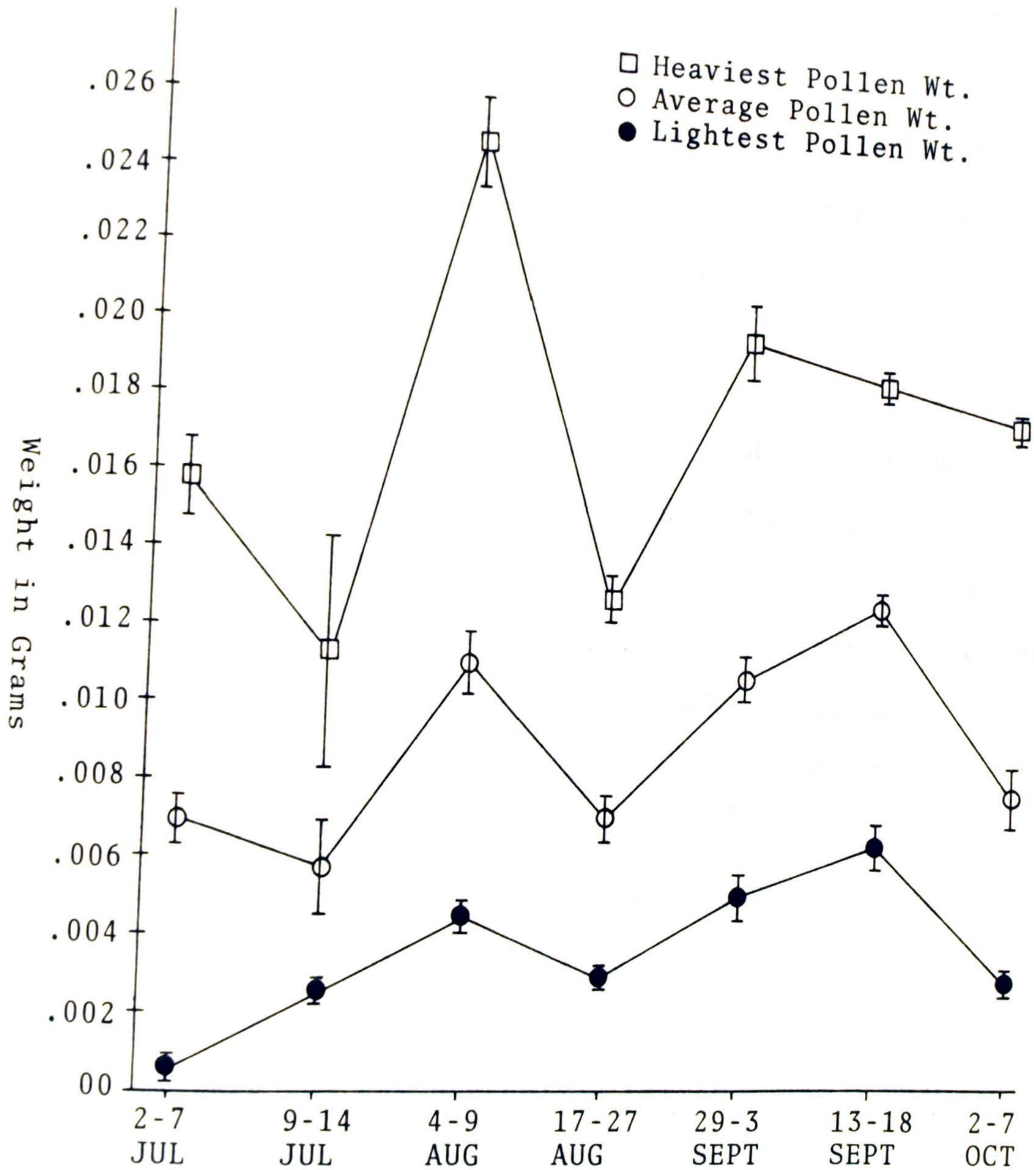

FIGURE 4. Pollen weights per trap period.

collected, Fig. 4 indicates that increases and decreases appear in the three weight classes simultaneously. Peak collections of pollen in this survey were taken during early July and the complete month of September (Fig. 5). The heaviest amount of pollen as shown in Fig. 3, was collected during the trap period of 4-9 August. However, this is actually the beginning of the dearth period for pollen collection and no explanation can be provided as to why the bees collected heavier loads on this one particular day.

Pollen and Body Weights

The body weights of pollen carriers and non-pollen carriers varied greatly in tests of individual bees. Of the total 8,796 honeybees trapped and observed, 1,052 were randomly selected and classified as pollen carriers. The mean body weight of this group of foraging bees was 89.3mg considering the entire test period at the 2:00PM CDT collection hour. Extremes of 63.0mg (lightest) and 135.1mg (heaviest) were also experienced. The average amount of pollen collected by the pollen carriers was 10.20mg for the entire time period.

Body weights for the non-pollen carriers had a mean of 92.3mg for the entire test period. The total random selection of bees measured as non-pollen carriers was 1,564. Extremes in body weight of non-pollen carriers varied more than the pollen carriers. Lightest bees measured 63.0mg

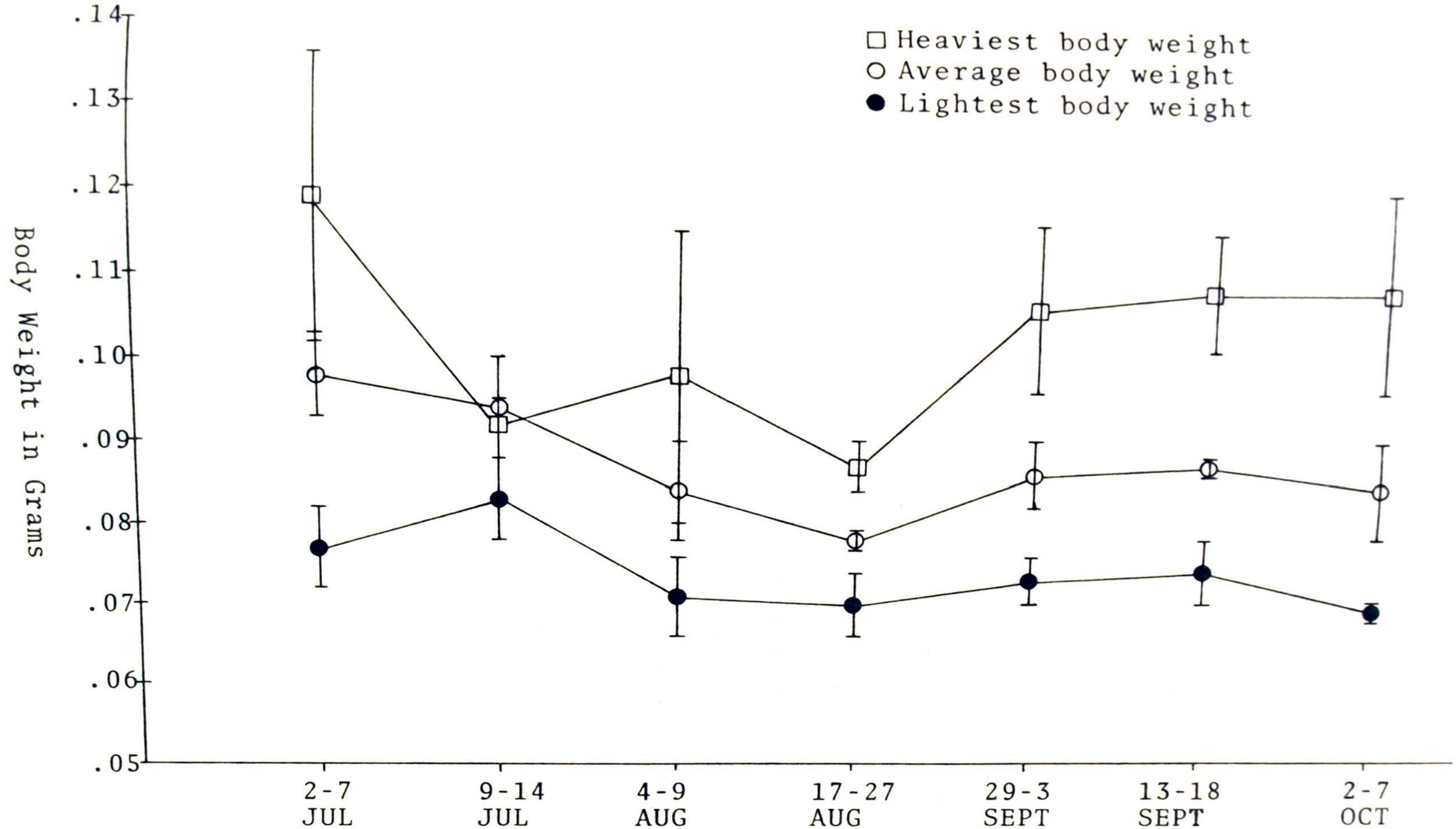

FIGURE 5. Mean body weights per trap period with pollen.

while the heaviest measured honeybee was 156.8mg. The heaviest extremes of the non-pollen carriers were trapped at the end of the nectar flow. Personal communication with local beekeepers revealed that the nectar flow for this area in Tennessee ends during the latter part of June and not later than mid July for this area on the Highland Rim.

Table III gives the mean body and pollen weights and the standard deviation of the mean per trap period. All weights are in milligrams. The mean body weight of bees returning to the hive without pollen (non-pollen carriers) were heavier in all trap periods (Fig. 6). In nearly all instances the standard deviation is greater for the non-pollen carriers than it is for the pollen carrier. The reason for this greater deviation of the mean could possibly be due to the inclusion of bees making their initial flights and not yet productive food gatherers for the colony. Bees with empty honeysacs would show a very light body weight as compared to the honeybees returning to the hive with full loads of nectar thus resulting in a wider range of weights.

There seems to be a similarity in the body weights of both pollen and non-pollen carrying bees as shown on Table III. Decreases in body weight occur in the same trap week as well as increases appearing in the same trap week. The mean weight of pollen did not seem to follow this pattern but depended more on foraging conditions.

Figures 5 and 6 illustrate the average body weights per

TABLE III. WEEKLY MEAN BODY WEIGHTS AND MEAN POLLEN WEIGHTS OF FORAGING HONEYBEES.

Month & Date	Mean Body Wt. Poll. Carriers	Mean Body Wt. Non-Poll. Carriers	Mean Pollen Weight
July			
2-7	97.9 ±5.30	99.4 ±7.60	7.1 ±2.90
9-14	93.6 ±1.50	95.5 ±4.54	5.7 ±6.25
August			
4-9	86.3 ±6.10	90.7 ±3.80	11.5 ±4.53
17-27	78.7 ±0.90	80.6 ±1.60	7.2 ±2.96
September			
29-3	85.9 ±4.00	88.7 ±7.20	11.0 ±2.66
13-18	87.4 ±1.50	90.2 ±4.80	13.0 ±1.76
October			
2-7	84.4 ±6.10	84.6 ±4.10	7.7 ±4.00

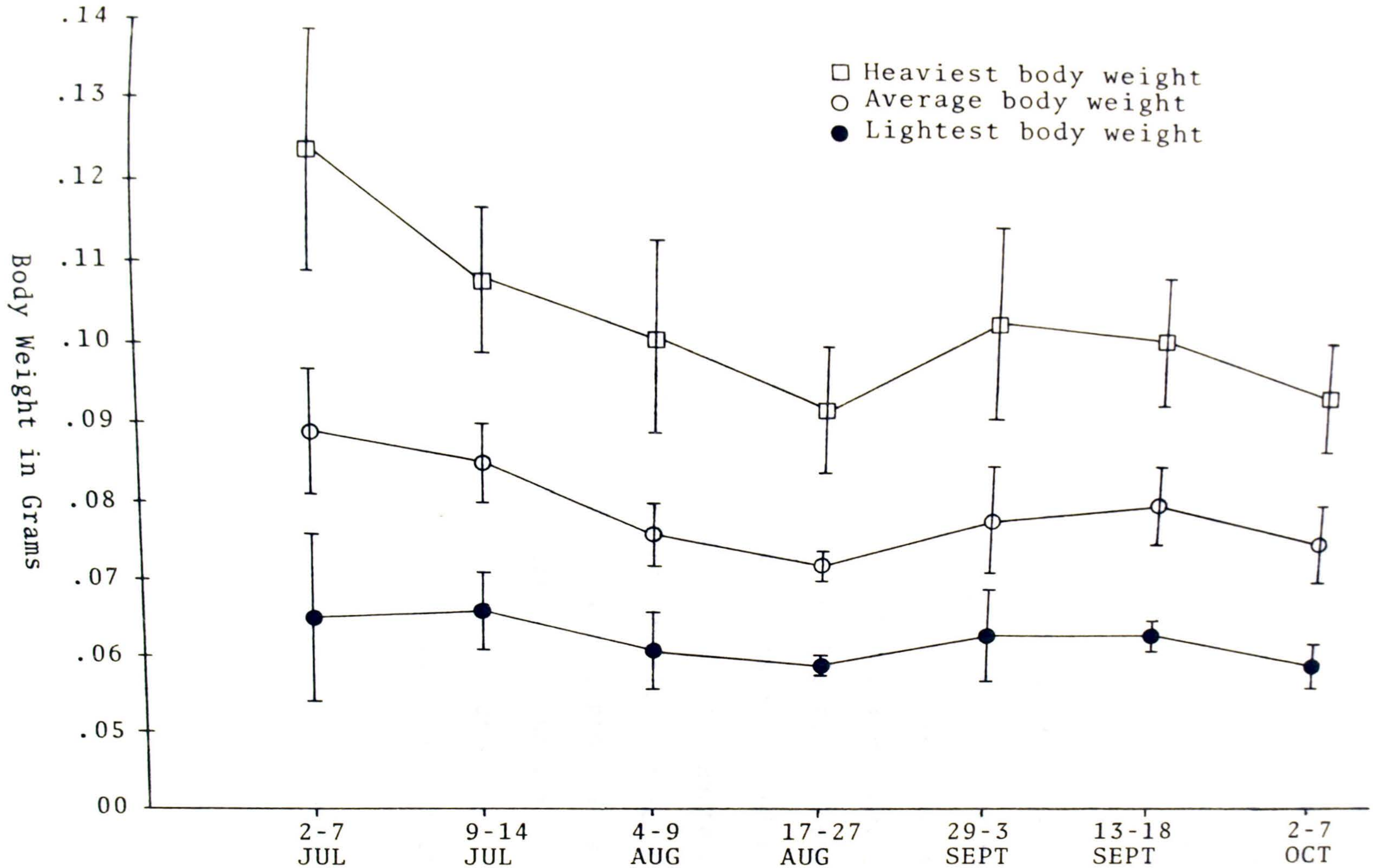

FIGURE 6. Mean body weights per trap period without pollen.

trap period with pollen and without pollen respectively. The heaviest and lightest body weights were obtained by going through the collected data and selecting either the heaviest or lightest bee per day per trap period and then arriving at a mean for the weekly collection. Average weights were determined by the mean of all 20 bees in the random selection.

Figure 5 shows an overlap in the standard deviation for the first three weeks of the study. During this time the pollen collecting bees were evidently collecting nectar at approximately the same rate as the non-pollen carriers. Since the nectar flow is ending during this time of the summer (after mid July) the last nectar is collected by both pollen and non-pollen carriers. After the month of August the body weights became significantly different possibly due to the reinstated flowering plants. This would seem to conclude that a portion of the pollen collecting bees are collecting pollen and nectar and another portion (the lightest body weights) are collecting only pollen.

From observations made during weighing procedures it was indicated that bees carrying above 10.0mg of pollen were usually older bees and perhaps more experienced in collecting.

Figure 6 shows that there is a significant difference between body weights of non-pollen carriers at 2:00PM. It should be noted that bees returning to the hive without pollen have a heavier body weight. This would seem to indicate that these bees can and do collect more nectar. Since these bees are not burdened with the weight of pollen then it would seem logical that they could fill the honeysac to capacity and therefore return to the hive with a heavier body weight. Fukuda et al. (1969) demonstrated that bees do not always collect nectar and/or pollen separately. He showed that an individual bee may collect pollen on one trip and the next trip the same bee may collect only nectar and the same bee on a third trip may collect both nectar and pollen.

The lighter bees are possibly those either unsuccessful in their foraging attempts or possibly those being new bees on their initial flights. The average weight as in Figure 6 is approximately that of the bees carrying pollen as shown in Figure 5. Although body weight was not the prime objective of this study it does show the specificity of the food collectors. Extremes of body weight were greater in the non-pollen carrying honeybees when compared to the pollen carriers.

The mean percent of pollen weight per body weight was 10 percent for the entire study period. Figure 7 shows that the percentage of the pollen weight per body weight of the honeybee increased throughout the study. Extremes of 0 to 35 percent of the bee body weights were recorded. The greatest extremes were found to be the brighter colored pollens. The lower extremes were usually the darker

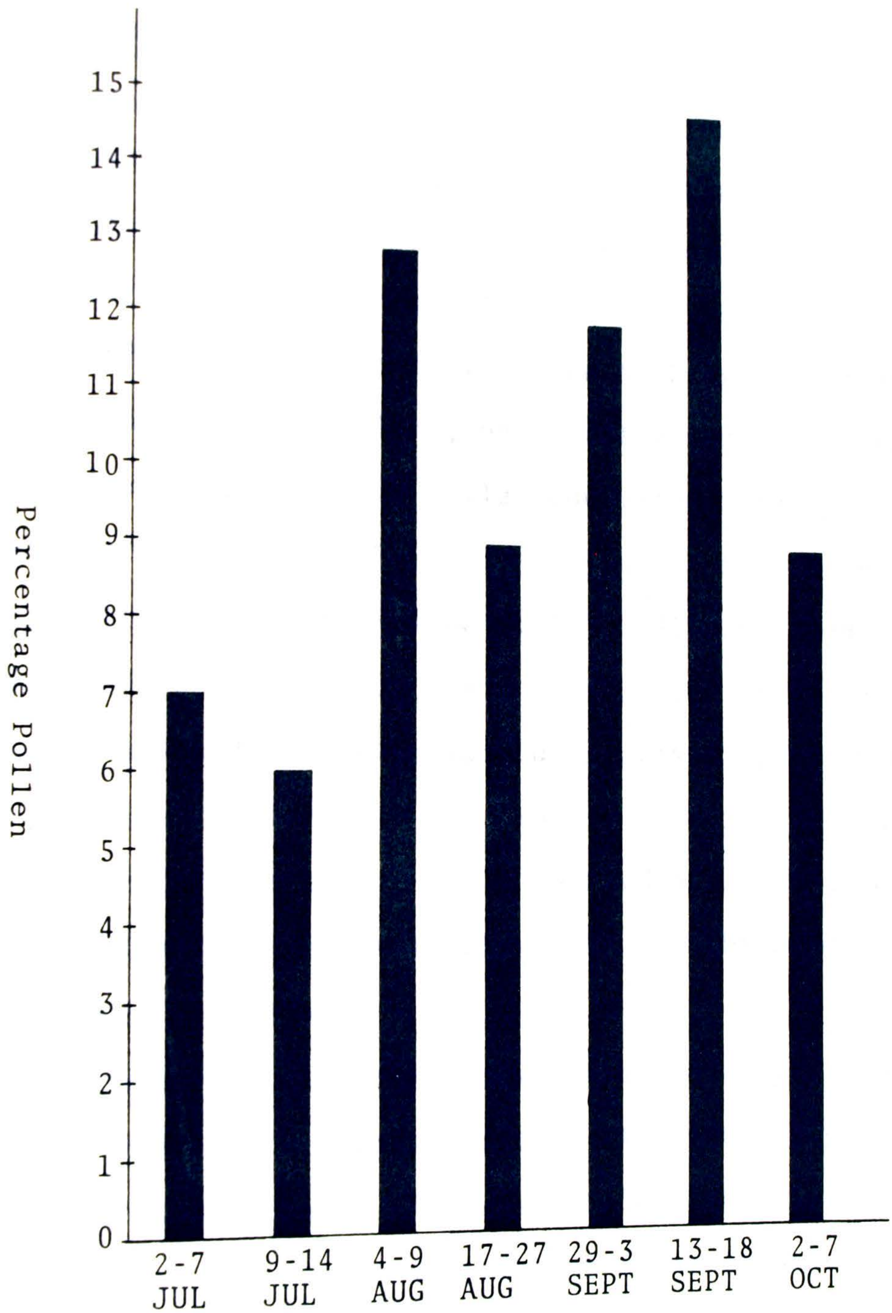

FIGURE 7. Percentage pollen per bee body weight.

color pollens and often collected on overcast days when foraging was also lower.

Color of Pollen

A color test was conducted on the pollen collected by the honeybees. No assay was made to determine the origin of the pollen. The color of the pollens was placed in 2 categories consisting of bright and dark. The bright category of pollen was to include the lighter and brighter colors such as bright yellow, pale yellow, orange, bright green and white. The dark pollen consisted largely of a drab olive color. Since the Trifolium repens (Percival 1949) and Trifolium hybridum (Fukuda et al 1969) have been recorded as the sources of which most pollen is collected it can be assumed that this made up a greater portion of the darker pollens collected. The clovers were in abundance for the greater portion of the summer (Gleason 1952) and bees were observed to forage these flowers throughout their flowering period.

The herbarium at Austin Peay State University has something over 800 different species of flowering plants listed and on reference. A study of the Land Between the Lakes has produced over 800 different flowering species and investigators of the area estimate that at least another 200 species will be found in that area. Similar figures have been estimated for Montgomery County, Tennessee.

On this basis we can assume that the brighter colored pollens are available to the honeybee on equal basis to that of the darker pollen. The darker colored pollens were collected to a greater extent than the brighter pollens during the first 2 trap weeks of the test (Fig. 8). This could be a result of several factors: First, a great number of clovers available per acre in the immediate vicinity of the hive. Since the bees had been transferred from another area they were just beginning to become oriented in the area and collected pollen at the closest source. Secondly, rain or overcast skies have allowed collections of legumes (Percival 1949). Overcast skies would usually result in lower temperatures and thus possibly forcing nearly all flowers to be less available during such weather. Sunny days did accelerate both the opening of the flowers and the foraging activity; therefore bursts of flowering coincided with peaks in pollen income (Percival 1949).

From the third trap week until the end of the study, bees collected more of the brighter colored pollens over the dark.

Behavior Test

Observations of bee activity were conducted to determine the effects of cold room temperatures (2 degrees C) on the honeybee.

Throughout the study the bees were allowed to remain in the cold room for a varying number of hours. Visual observations revealed that bees become completely immobi-

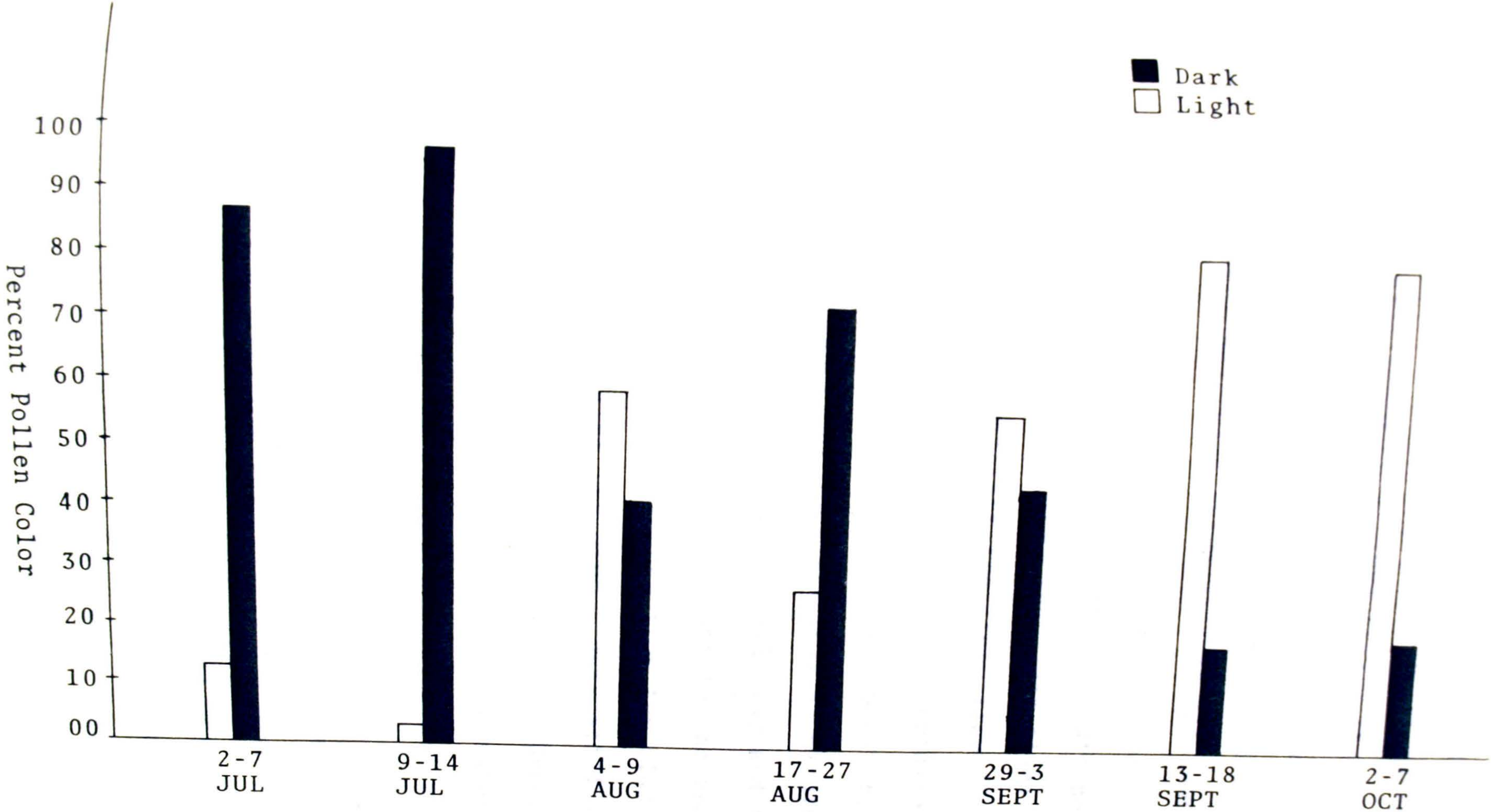

FIGURE 8. Color of pollen carried per trap period.

lized at 27 minutes when the bees are isolated from the clump (moving together or a cluster). In clumps the movement occurred at a rapid pace. The longer the bees endured the cold room temperatures the smaller the clump became. The bees that clumped did so within approximately 4-7 minutes after the bees were introduced to the lowered temperature conditions. Often 2-3 small clumps were evident at the beginning of the test by by the 7 minute point the small clumps dispursed and joined the large clump.

Some of the bees that left the clump flew for a short period and then walked rapidly around the container. Between 20 and 27 minutes those bees not in the clumps still had nearly normal movement. At approximately 43 minutes the outer portion of the clump began to fall away and therefore exposed the warmer bees inside the clump to the reduced temperatures. The bees that dropped from the clump had no movement 2 minutes after the drop. Bees still in the clump had reasonable mobility and maintained movement for approximately another 27-30 minutes. At 70 minutes, movement ceased, leg twitching stopped and abdominal constrictions were no longer evident.

Bees removed from the cold room after 70 minutes were subjected to room temperatures. Within 3-5 minutes the abdominal contraction was the first sign of any movement within the body. Shortly thereafter, leg twitching began and walking at an unsteady pace followed. Within 18 minutes the bees were totally mobile and able to fly away apparently unharmed by the cold treatment. An increased time in the cold room was proportional to the immobility of the bees. Two hours of cold treatment extended immobility for 20-25 minutes depending on the number of bees in the test.

Extended periods of cold treatment showed that bees could withstand the treatment for a maximum of 8 hours. Beyond 8 hours of cold at 2 degrees C. effected the mobility of the honeybee to an extent that it became lethal. Although bees were able to move when allowed to warm to room temperature their mobility was limited to movement of the legs and walking. After 24 hours of the treatment, bees would move for a short period then die. No flying or wing flapping was observed after these extended periods of cold treatment.

CHAPTER V

DISCUSSION OF RESULTS

A difference in the amount of pollen carried at the different sampling times cannot be determined from the graph of Figure 1. An overlap in the standard deviation does indicate that there is no significant difference in the weight of pollen loads. The 6:00PM CDT could not represent the maximum collection of pollen since the bees on several instances had little or no pollen on their corbicula. A decision had to be made as to the time of day that pollen would be collected in greatest amounts. Calculations showed that more bees were in the field foraging at 1:00PM CST and that more bees were returning to the hive with pollen at this midday hour. Jaycox (1970b) in working with soybeans and honeybees, showed that the percentage of pollen loads increased from 28 percent at 8:45AM CST to 64-67 percent at midday (1:00CST) in Urbana, Illinois. Holmes (1964) showed that greatest percentage of honeybees are foraging at the midday hour. It seems logical that since bees forage heaviest at midday the greater portion of pollen is collected at that time. This physiographical region, on the evidence presented above does not alter the collection times of the honeybee.

This regional location does allow the honeybee to forage for extended periods in the latter afternoon hours. Jaycox showed that foraging in Urbana, Illinois is almost nil at 4:00PM. Figure 1 demonstrates that bees were often collecting and returning with pollen at 6:00PM. Visual observations of bees entering the hive at times later than 6:00PM would seem to suggest that foraging is continued until sometime near sunset at this location. Difference in the foraging activity might be attributed to light intensity, location, elevation, flower source or the many weather factors peculiar to a certain location. Pellett (1947) found a great deal of difference in foraging activity. He stated that in Tennessee honeybees had a much longer activity period than in North Carolina. He found that in Tennessee bees were active in the field from 9:00AM to sunset while in North Carolina foraging activity ran from early morning until noon or 1:00PM. Evidently the activity range of the honeybee here on the Highland Rim is much longer than at other locations throughout the United States.

Figure 2 represents the total pollen acquisition throughout the entire test. The sampling of 20 honeybees per day does not show the difference in body weight that is present in individual bees, although the extremes are not evident, they are shown in the standard deviation. Body weights are varried by a number of influences such as age, nectar availability, weather, etc.

Johnson (1944) found heavy weight gains during the months of July and August at Urbana, Illinois and similar results have been recorded by Jaycox (1970b) in recent years. This would indicate that flowering occurs later in Illinois than in Tennessee. Figure 3 illustrates that the month of August is a lax period for flowering plants in middle Tennessee. Personal communication with local bee-keepers denotes that observations in their bee yards would find the bees merely remaining close to the hive and making little effort in collections of pollen or nectar. This can be seen in the results as illustrated by Figure 3. Weather conditions did not influence collection during that particular month.

Table I lists the weather during the trap days along with the preceding and following days. It has been known for a great number of years that weather has a strong influence in the honeybee and honey production. Mid July (13, 14, 15, 16, 17, 18, 19, 20, 21) provided weather conditions unfavorable for foraging activity. The highest wind throughout the test occurred during this time. This trap period was not included in the selection of trap weeks for the study since it did have unusual circumstances that effected the pollen collections as well as foraging.

An overcast sky was the biggest factor in hampering pollen collection except for days when precipitation occurred during or near the trap time. The cloud cover classification of overcast usually resulted in lower temperatures and thus effecting collection of pollen by foraging bees. Collections were smaller and the percentage of bees collecting pollen was also smaller. Temperature changes were usually below 26 degrees C in overcast days. Temperatures of 26 degrees C or above have been demonstrated to be effective in colony weight gains (Johnson 1944, Moffett and Parker 1953, Jaycox 1970a). On a few occasions the temperatures were above 26 degrees C during overcast days and bees returning with pollen were equal to days with no cloud cover.

No significant differences appeared in clear days or scattered days or days declared as clear to scattered. Table II shows that mean weight on the clear, clear to scattered and scattered days did not differ greatly while the overcast days dropped significantly and illustrates the difference. Weather is shown to be a highly effective factor as shown in Table II. Cloud cover such as overcast would influence the light source and the light source in return would usually result in lower temperatures and this would thus effect the flowers and the bees in a chain like reaction. Hammer (1940) as stated by Devlin (1968), studied the quantitative effect of light duration intensity on floral iniation by soybean on a photoinductive cycle. He found that at light intesities below 100ft-c, no flowers are produced. An increase in light intensity increases the number of flowers produced. This varies with type and species of flowers but could be a possibility to reduce foraging and collection of pollen on overcast days.

Figure 4, 5, and 6 deal with weights of pollen and the bees per trap period. Each figure had the weights placed into three categories: light, heavy and average. The lightest weights (Fig. 5&6) are probably bees without nectar in the honeysacs. In Fig. 5 this would demonstrate that the lightest bees are pollen collectors only and that the heaviest bees are pollen and nectar carriers. The difference in body weight is even more noticeable when foraging bees are returning without pollen. This would show that some bees are carrying only nectar loads. These results suggest that not all foragers specialized exclusively either in nectar or pollen foraging. Fukuda et al. (1969) stated that the proportion of bees specializing and those foraging both pollen and nectar is determined by the kind of pollen source plants on which they are working. He further stated that crop weight in pollen foragers is even larger in nectar foragers when the source is white clover.

The average percentage of pollen carried by individual bees was 10 percent. Although percentages fluctuated with environmental conditions an increase in weight of pollen is seen in Figure 7. September was the month when the late summer flowers began to bloom (probably asters and golden rod) after the lax flowering period of August. The increase in the percentage of pollen weight per bee body weight is seen in the first trap period in September. In comparison Figures 4, 5, 6, and 7 all show a similar increase that begins after the month of August.

Jaycox (1970a) states that foraging bees select the more attractive and productive flowers from among those available at the same time. Figure 8 shows that the dark colored pollens were gathered in abundance at the beginning of the study. Although the brighter colored pollens were available the bees were not totally familiar with the foraging area since they were moved into the new beeyard a few days before the test began. Percival (1947) found that bees will collect pollen readily from the nearest source of flowers. This is indicated in Figure 8. It is thought that since the number of flowering species is high in the collection area at Austin Peay State University campus the bees did have equal opportunity to collect from both light and dark pollen sources. However, after the second trap period the darker pollens were collected in fewer quantities and the brighter pollens to a greater extent. It seems that the bright pollens are more attractive to the bees when a choice between the two can be made. Not only is more bright pollen brought into the hive but the brighter pollen loads are heavier.

CHAPTER VI

SUMMARY

An investigation of *Apis mellifera* pollen weights and foraging activity was conducted from June 28 to October 7, 1971. During that time a total of 8,976 honeybees were trapped and observed. Of the total honeybees trapped, 1,564 were randomly selected and weighed as non-pollen carriers and 1,052 randomly selected as pollen carriers. The pollen carriers had their pollen pellets removed and weighed individually. These results showed the following:

(1) pollen in this geographical location on the Northwestern section of the Highland Rim is collected from early morning until almost sunset and reaching a peak at midday.

(2) a greater percentage of bees are foraging at the midday hour.

(3) pollen collections show a decrease when the nectar source is unavailable and an increase when the nectar source is abundant.

(4) the greatest amount of pollen is collected on clear days when compared to overcast cloud cover.

(5) the brighter colored pollens are more readily selected by honeybees over the darker colored pollens.

(6) the mean percentage of pollen per bee weight

is 10 percent with a range of 0-35 percent.

(7) weather conditions are easily correlated with pollen collections.

(8) the average weight of pollen is 10.2mg per bee and the average body weight for pollen carriers is 89.9mg while non-pollen carriers averaged 93.0mg body weight.

(9) worker bees under isolated conditions could withstand lowered temperatures for a short period of time before those temperatures became lethal.

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