FACTORS AFFECTING HONEY BEE FORAGING BEHAVIOR ON WATERMELON, *Citrullus lanatus* (Thunb.) Mans.

by

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TABLE OF CONTENTS

	Page
LIST OF TABLES	v
LIST OF ILLUSTRATIONS	vi
ABSTRACT	vii
INTRODUCTION	1
MATERIALS AND METHODS	2
Cultivar Descriptions	2
Flower Morphology	2
Plot Design	6
Culture Techniques	9
Floral Observations	11
Bee-Flower Relationships	19
RESULTS AND DISCUSSION	33
Floral Observations	33
Bee-Flower Relationships	37
SUMMARY AND CONCLUSIONS	54
REFERENCES CITED	58

LIST OF TABLES

Table		Page
I	Time of anthesis in the cultivar Peacock. Tucson, Arizona. June 1966	13
II	Time of anthesis in the cultivar Peacock (P.) and the male sterile line (M.S.). Tucson, Arizona. June 1967	14
III	Time of closing of Peacock cultivar flowers. Tucson, Arizona. June 1966 . .	15
IV	Time of closing of flowers in the cultivar Peacock (P.) and the male sterile line (M.S.). Tucson, Arizona. June 1967	16
V	Number of anthers dehisced at 0630 Daylight Saving Time and pollen availability in the cultivar Peacock. Tucson, Arizona. June 1967	18
VI	Time and volume of nectar secretion, expressed in microliters, for the cultivar Peacock and the male sterile line (M.S.). Tucson, Arizona. July 1967 . .	20
VII	Time of anthesis and mean volume, and percent soluble solids of nectar secretion compared with the field population on a bee/flower basis for the cultivar Peacock. Tucson, Arizona. July 1967 . .	25
VIII	Mean percent of soluble solids in samples taken from bee honey stomachs. Tucson, Arizona. July 1967	27
IX	Effect of bee visit numbers on fruit set in Peacock watermelon. Tucson, Arizona. 1966	51

LIST OF ILLUSTRATIONS

Figure		Page
1	Staminate flower of the cultivar Peacock	4
2	Pistillate flower of the cultivar Peacock	5
3	Pistillate flower of the male sterile line	7
4	Watermelon plot design used in the 1966 investigations	8
5	A honey bee using the preliminary stance on a staminate Peacock flower	22
6	A honey bee using the terminal stance on a staminate Peacock flower	23
7	Photomicrograph of pollen grains removed from the anther surfaces of a staminate Peacock flower	29
8	Photomicrograph of pollen grains from a corbicular pellet removed from a honey bee collecting pollen on a staminate Peacock flower	30
9	Photomicrograph of pollen grains from a corbicular pellet removed from a honey bee at the entrance to a nearby hive . . .	31

ABSTRACT

Preliminary observations on honey bees (Apis mellifera L.) foraging on watermelon (Citrullus lanatus (Thunb.) Mans.) indicate that there is a definite relationship between the field population density and the time of floral anthesis and pollen availability. The population density is higher during the time of nectar secretion. These observations were made during the months of June and July in 1966 and 1967 at The University of Arizona Experiment Station's Alley Road Farm in Tucson, Arizona.

The honey bees working on watermelon appear to use their proboscises for pollen gathering as well as for nectar collection.

A few honey bees were seen working on the flowers of both watermelon and cantaloupe (Cucumis melo L.) on the same foraging trip.

INTRODUCTION

The watermelon plant Citrullus lanatus (Thunb.) Mans. is pollinated by bees and chiefly by the honey bee Apis mellifera L. (Jones and Rosa 1928, Goff 1937). Studies dealing primarily with the effects of honey bee visitation on fruit development in watermelons have been conducted by Rosa (1925), Jones and Rosa (op. cit.), Goff (op. cit.), and Adlerz (1966).

Adlerz (op. cit.), working with honey bees on the watermelon cultivar Charleston Gray, concentrated his efforts on the number of visits necessary to set a melon that would grow to maturity. The emphasis in these preceding studies has been on the botanical aspects of watermelon fruiting and its dependence on the honey bee. No detailed observations of honey bee behavior during pollination flights to watermelon plants have been reported. It is, therefore, the purpose of this paper to investigate some of the factors which affect the pollination behavior of the honey bee on the Citrullus lanatus cultivar, Peacock and a male sterile line.

MATERIALS AND METHODS

Cultivar Descriptions

The watermelon cultivar Peacock was used to obtain honey bee behavioral data during the summer of 1966. In the investigations conducted in the summer of 1967, Peacock was again used in addition to a male sterile line. Peacock is a recent cultivar introduced in 1939 by George Stratis at Brawley, California. The male sterile line is not a commercially cultivated variety.[1]

Flower Morphology

The expression of flowers in Citrullus lanatus is usually monoecious (Whitaker and Davis op. cit.) although a few cultivars are known to be andromonoecious. The staminate flowers are arranged on the stem so that there are six male flowers at each of six consecutive nodes; the seventh is occupied by a pistillate flower (Rosa op. cit.). The large pinnate leaves and one forked tendril are also to be found at each node.

---

1. The male sterile line seed obtained from the DeKalb breeding department of DeKalb Agricultural Association Incorporated, DeKalb, Illinois.

The staminate flower is a rather shallow "dish" as can be seen in Figure 1. In the cultivar Peacock, the five petals of the corolla are a greenish yellow color with definite yet very small veins coursing throughout each petal. On each petal there are also very prominent nectar guides that run vertically down to the base of the corolla.

The stamens are three in number, and they are individually attached at the base of the corolla. The nectary tissue lies inside a small cup formed by the bases of the filaments, the entrance to which is also between the bases of the filaments. A single stamen is very short, being approximately as long as the height of the anther it bears. The anther surface is yellow in color and folded and convoluted so that all three anthers together very much resemble a piece of Brain Coral.

The parts of the staminate flower of the male sterile line are similar except that the petals are thicker, more green than yellow, and the stamens and anthers are reduced to a clump of twisted tissue at the bottom of the corolla.

The pistillate flower (see Figure 2) of the Peacock watermelon also bears five petals that form a shallow dish-like corolla. The three papillate stigmas

Figure 1. Staminate flower of the cultivar Peacock

Figure 2. Pistillate flower of the cultivar Peacock

are borne on a fused style -- three styles "fused" into one (Whitaker and Davis 1962.) -- that is only slightly longer than the height of the stigmas. The ring-like nectary is located at the base of the style.

The pistillate flower of the male sterile line (see Figure 3) is morphologically similar to the Peacock flower except that, again, the color of the petals is more green than yellow, the petals are very narrow, and the stigmas are longer and bulbous.

The branches or main stems, three to eight in number, bear primary branches, and the primary branches may, in turn, bear several secondary branches; these, however, are usually shorter and not as thick in diameter.

Plot Design

The fields described below were located at the University of Arizona Agricultural Experiment Station on Allen Road Farm in Tucson, Arizona.

The plot used in the 1966 experiment contained 13 rows or beds, each planted with 30 plants 48" apart. Forty-eight inches was also the distance from center to center of each bed (see Figure 4). Some of the plants failed to emerge or mature (indicated by a space in Figure 4). The 30 dots enclosed in the square in the

Figure 3. Pistillate flower of the male sterile line

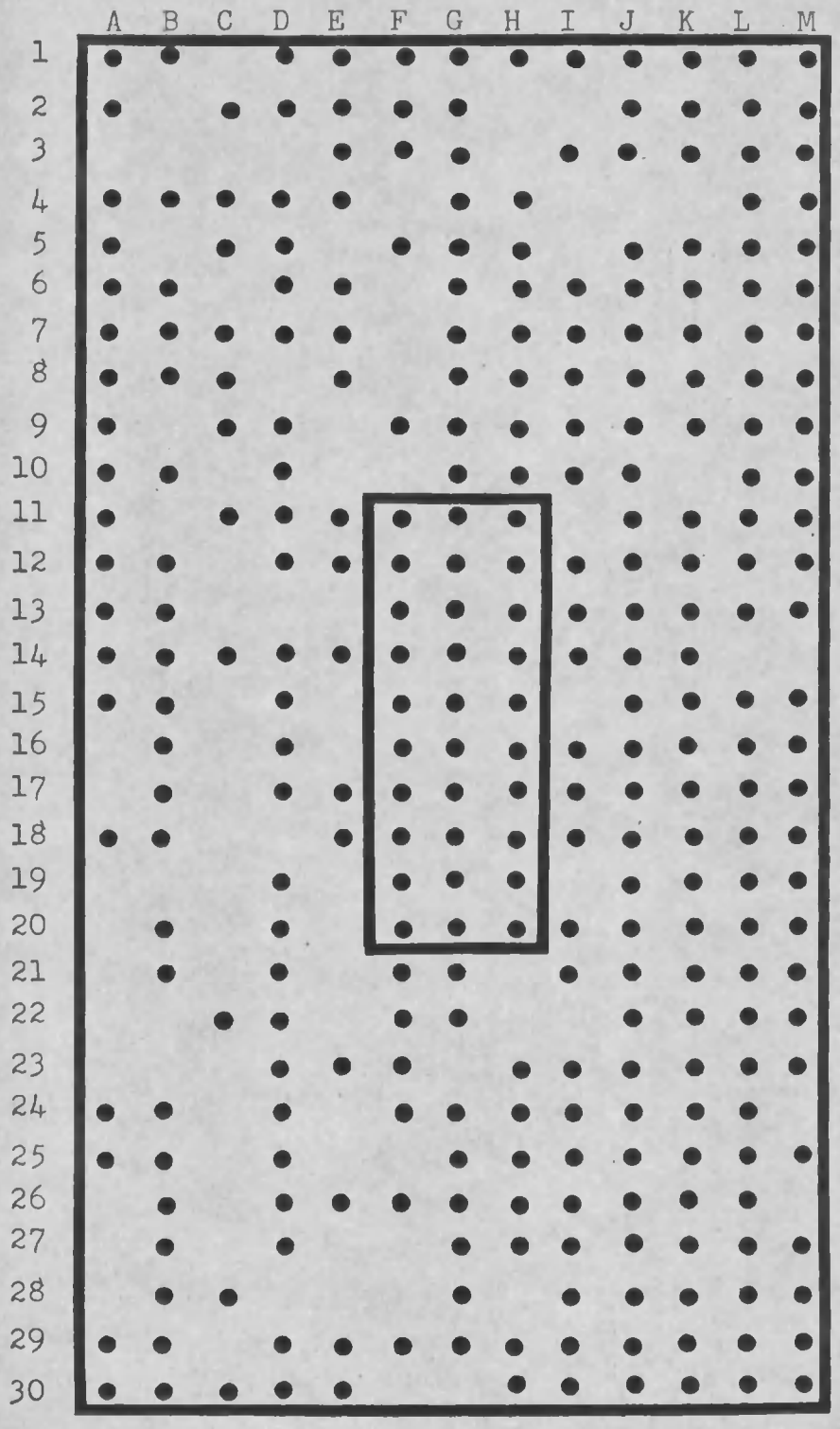

Figure 4. Watermelon plot design used in the 1966 investigations

center of the diagram (Figure 4) represent the Peacock cultivar, and the surrounding dots indicate a triploid and tetraploid mixture of watermelon plants. Data taken on the latter plants are not included in this paper due to the unknown pedigree of the plants.

The plot used in the 1967 investigations was slightly larger -- 13 beds 72" from center to center with the 30 plants in each bed 72" apart. The plot design for 1967 was the same as that used in 1966 (see Figure 4). In 1967 the dots in the center would represent Peacock plants and the surrounding dots would be the male sterile line plants.

Culture Techniques

In 1966, young plants in peat pots were transplanted into the field. The field was later rogued, leaving only the best plants. However, 86 plants either failed to grow or died before maturing. Regular cultural practices were followed with weeding done by hoeing and irrigation on a once weekly schedule. In 1967, seedlings were grown by Dr. R. E. Foster, Horticulturist at the Crops Research Experiment Station of the University of Arizona at Mesa, Arizona. Sixteen seedlings of the original planting died and were replaced shortly thereafter. Out of the 16 replacements, only 4

died and were not again replaced. The same cultural practices were used in 1967 with the exception that one application of Diazinon spray at 0.75 lbs. actual per acre was made to control spider mites, Tetranychus telarius L., just as the plants were beginning to vine. Inspection one week after application showed that the treatment effectively controlled the mites.

In 1966, eight two-story colonies of honey bees were used -- four at each end of the plot. Two colonies at each end of the plot were equipped with pollen traps during the first week of the experiment; following the first week, however, these were removed permanently. The pollen traps were used to gather incoming pollen specimens to see if melon pollen was being brought back to the hives. Weekly examinations of the colonies were made, and the condition of each queen was noted.

In addition to the above colonies, there were eight colonies within 30 yards of the plot and 10 colonies within 100-250 yards.

Several more colonies were located within one-fourth mile of the field. According to Ribbands (1951), colonies within at least three-eighths mile should be considered as possible sources of foragers. It was impossible to calculate a precise colonies-per-acre figure in this experimental situation, but it was felt

that the number of colonies was more than sufficient for adequate pollination. Some conclusions were drawn concerning the effect of this potentially high population, and they are listed under the heading Miscellaneous Observations.

In 1967 more than 50 colonies were within easy flight range of the plot. One two-story colony was placed along one side of the 1967 plot. A pollen trap was attached to help determine if watermelon pollen was being brought to the hive.

Floral Observations

a) Time of anthesis. In the 1966 test, the 10 Peacock plants of Row G (Figure 4) were used to determine the time of anthesis, synonymous with flower opening, and closing of the flowers. Beginning at 0650, all of the open flowers in that row were counted and recorded every 10 minutes until 0800. At 1000 hours all visible flowers were counted again to obtain a total number of flowers. It was observed that all flowers opening on each day would be opened by 1000 hours, and this number was then used to calculate percent open. The counts were made on the second through the seventh days following irrigation, including both staminate and pistillate flowers. The same

procedure was followed on Peacock plants in the 1967 tests and on the male sterile line, using 50 feet of Rows A and K. The results of these observations may be found in Tables I and II.

The same procedure was followed to determine the time of closing of the flowers. Closed flowers were counted at 1300 and every 20 minutes thereafter until 1430. The 1000 hours total count in the time-of-anthesis observation was used as the basis for a percent-closed figure (Tables III and IV).

b) Anther dehiscence. The second factor which was investigated (in 1967 only) was the time of anther dehiscence. In order to relate the presence of the bees at anthesis to pollen-collecting behavior, a determination of the time of anther dehiscence was made by inspection.

In pre-experiment observations on the male sterile line flowers, dehiscence, if it took place at all, could not be detected. No pollen was ever seen in the staminate flowers.

At 0630, approximately 13 minutes after sunrise, 25 staminate Peacock flowers in Row G were forcibly opened, and the anther condition was observed. As the anthers were examined, a small square of clean dry paper was touched gently to the surface to see if

Table I.--Time of anthesis in the cultivar Peacock. Tucson, Arizona. June 1966.

June Hours[c]	19[a] % open	20 % open	21 % open	22 % open	23 % open	24[b] % open
0650						
0700				7.4	25.0	
0710		8.1	26.0	25.9	32.1	41.1
0720	13.7	18.4	56.5	37.0	50.0	50.0
0730	39.2	26.3	73.9	51.8	82.1	55.8
0740	45.0	42.1	86.9	51.8	82.1	67.6
0750	49.8	65.7	91.3	74.0	89.2	79.4
0800	70.5	73.6	91.3	85.1	100.0	85.2
1000	51[d]	38	23	27	28	34

a) Sunrise for June 19-22 was at 0517 and on June 23 it was at 0518.

b) June 24 - overcast sky until 0700.

c) Hours listed are Mountain Standard Time.

d) Total number of flowers for the day = 100%.

Table II.--Time of anthesis in the cultivar Peacock (P.) and the male sterile line (M.S.). Tucson, Arizona. June 1967.

June	[a]12		13		14		15		16		17	
	(P.)	(M.S.)[b]	(P.)	(M.S.)	(P.)	(M.S.)	(P.)	(M.S.)	(P.)	(M.S.)	(P.)	(M.S.)
Hours	% open	% open	% open	% open	% open	% open	% open	% open	% open	% open	% open	% open
0650									8.8	63.6		
0700			11.4		9.8		13.7	16.6	20.5	81.8	24.2	
0710	7.3		14.7	55.5	21.5	55.5	20.6	41.6	41.1	90.9	51.5	50.0
0720	19.5	25.0	37.7	77.7	50.9	88.8	62.0	58.3	52.9	100.0	75.7	75.0
0730	51.2	50.0	83.6	77.7	74.5	100.0	68.9	83.3	79.4	100.0	90.9	100.0
0740	82.9	50.0	95.0	100.0	78.4	100.0	79.3	100.0	82.3	100.0	100.0	100.0
0750	87.8	75.0	100.0	100.0	84.3	100.0	93.1	100.0	91.1	100.0	100.0	100.0
0800	90.2	75.0	100.0	100.0	86.2	100.0	93.1	100.0	97.0	100.0	100.0	100.0
1000	41[c]	8	61	9	51	9	29	12	34	11	33	8

a) Sunrise for June 12-15 was at 0518, and June 16-17 it was 0519, Daylight Saving Time

b) All pistillate flowers

c) Total number of flowers for the day = 100%

Table III.--Time of closing of Peacock cultivar flowers. Tucson, Arizona. June 1966.

June Hours	19 % closed	20 % closed	21 % closed
1300			34.7
1320	31.3	31.5	52.1
1340	72.5	47.3	69.5
1400	88.2	68.4	78.2
1420	100.0	81.5	100.0
1430		100.0	

Table IV.--Time of closing of flowers in the cultivar Peacock (P.) and the male sterile line (M.S.). Tucson, Arizona. June 1967.

June	12		13		14	
	(P.)	(M.S.)	(P.)	(M.S.)	(P.)	(M.S.)
Hours	% closed	% closed	% closed	% closed	% closed	% closed
1300					21.5	22.2
1320	29.2	-	22.9	-	31.3	22.2
1340	56.0	62.5	37.7	22.2	52.9	66.6
1400	73.1	62.5	65.5	55.5	90.1	77.7
1420	92.6	100.00	100.0	100.0	100.0	100.0
1430	100.0					

the pollen had been released. The pre-anthesis observation was conducted on three succeeding days -- the second, third, and fourth days after irrigation. The times of sunrise and the results of the observations on anther dehiscence are found in Table V.

c) Nectar secretion. The next factor which was investigated was the time of nectar secretion. Pre-experiment observations revealed that nectar was never present before 0900 in either the staminate or pistillate flowers of both lines. These observations were made by examining with a 5x hand lens the nectaries of both male and female flowers.

The extent of nectar secretion was determined as follows: Ten blossoms of the Peacock cultivar and ten of the male sterile line were tagged. Each was carefully covered with a 2" x 2" loose-knit cotton bag to prevent bee visits.

A ten-microliter syringe (Hamilton Co., Model 701N) of the type used in gas chromatography was used to withdraw nectar from the nectary areas. The .0045" I.D. 2" needle on the syringe was blunted on the end to prevent damage to plant tissues. Samples were taken from each blossom once during each half hour from 0900 until no bees were observed in the field for at least one half hour. Tests were made on the third and

Table V.--Number of anthers dehisced at 0630 Daylight Saving Time and pollen availability in the cultivar Peacock. Tucson, Arizona. June 1967.

	June		
	19	20	21
Number inspected	25	25	25
Anthers dehisced	25	23	25
Pollen available	Yes	Yes (23) No (2)	Yes

fourth days following irrigation. The mean amounts withdrawn and the times of withdrawal are listed for staminate and pistillate flowers, for 1967 only, in Table VI.

Bee-Flower Relationships

a) Individual behavior. A detailed, close-up study of individual behavior of bees on the staminate and pistillate flowers was made with the help of a hand lens, a camera, and considerable patience. (See Figures 5 and 6). Observations were made in both 1966 and 1967, and the results are described on page 37.

b) Nectar, pollen and bee visitation. The time of nectar secretion and of anthesis and pollen availability were observed together with population fluctuations. This investigation was made to determine if a definite relationship existed between nectar secretion, pollen availability, and the field population of honey bee foragers.

This observation was conducted only in 1967, and due to a paucity of the male sterile line blossoms during the sampling days, results were obtained only for Peacock. Population counts were made on a 50-foot row basis, recording on a hand counter the number of bees seen in the flowers. Three separate

Table VI.--Time and volume of nectar secretion, expressed in microliters, for the cultivar Peacock and the male sterile line (M.S.).
Tucson, Arizona. July 1967.

	July 3						
	0900	0930	1000	1030	1100	1130	1200*
No. of flowers sampled:							
Peacock							
staminate	7	7	7	7	7	7	7
pistillate	3	3	3	3	3	3	3
M.S.							
staminate	3	3	3	3	3	3	3
pistillate	7	7	7	7	7	7	7
Mean volume of nectar withdrawn:							
Peacock							
staminate	0.0(+)	0.0(+)	.12	.25	1.01	0.37	0.11
pistillate	0.0(+)	0.0(+)	0.0(+)	0.30	0.66	0.36	0.06
M.S.							
staminate	0.0	0.0(+)	0.0(+)	0.06	0.33	0.13	0.03
pistillate	0.0	0.0(+)	0.07	0.14	0.97	0.28	0.14
Range:							
Peacock							
staminate	-	-	0.4	0.6	1.8	0.4	0.4
pistillate	-	-	-	0.9	2.0	0.2	0.2
M.S.							
staminate	-	-	-	0.1	0.4	0.3	0.1
pistillate	-	-	0.3	0.4	2.2	0.6	0.3

* = no bees foraging after 1200.

(+) = nectar present, not in quantitative yield.

Table VI.--Continued

	July 4						
	0900	0930	1000	1030	1100	1130	1200*
No. of flowers sampled:							
Peacock							
staminate	6	6	6	6	6	6	6
pistillate	4	4	4	4	4	4	4
M.S.							
staminate	1	1	1	1	1	1	1
pistillate	9	9	9	9	9	9	9
Mean volume of nectar withdrawn:							
Peacock							
staminate	-	0.1	0.1	0.31	0.06	0.01	0.05
pistillate	-	0.0(+)	0.7	0.35	0.1	0.02	0.02
M.S.							
staminate	-	0.0	0.0(+)	0.2	1.0	0.3	0.2
pistillate	-	0.02	0.04	0.15	0.44	0.1	0.05
Range:							
Peacock							
staminate	-	0.2	0.4	0.9	0.2	0.1	0.2
pistillate	-	-	0.3	0.6	0.1	0.1	0.1
M.S.							
staminate	-	-	-	0.2	1.0	0.3	0.2
pistillate	-	0.2	0.4	0.4	1.0	0.9	0.2

* = no bees foraging after 1200.

(+) = nectar present, not in quantitative yield.

Figure 5. A honey bee using the preliminary stance on a staminate Peacock flower

Figure 6. A honey bee using the terminal stance on a staminate Peacock flower

counts were made during each half-hour period. At 1000 hours the total number of visible flowers was counted and recorded.

In 1966 the above counting method was compared with two other techniques in an 85-acre cucumber field at Amado, Arizona. Resulting statistical analysis demonstrated that traversing 50 feet of row was as accurate as the other more laborious counting methods.[1]

The times of anthesis and nectar secretion were also noted. Nectar secretion was measured as described above. In addition, the percent of soluble solids in each nectar sample was recorded from readings made on a Bausch and Lomb hand refractometer (scale: 0 to 60%). The nectar measurements were made on 10 blossoms, and the results are presented in Table VII. Squeezing the abdomen of the honey bee produced a drop of clear fluid at the mouthparts. These samples from the honey stomach were also read for percent soluble solids on the hand refractometer (Table VIII).

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1. The data from the cucumber experiment are now being submitted for publication in a paper authored by Dr. M. D. Levin, U.S.D.A. Bee Research Laboratory; Dr. R. O. Kuehl, Associate Professor of Statistics at the University of Arizona; and R. V. Carr, Research Assistant at the U.S.D.A. Bee Research Laboratory.

Table VII.--Time of anthesis and mean volume, and percent soluble solids of nectar secretion compared with the field population on a bee/flower basis for the cultivar Peacock. Tucson, Arizona. July 1967.

		Hours								
	July	0700-0730	0730-0800	0800-0830	0830-0900	0900-0930	0930-1000	1000-1030	1030-1100	1100-1130	1130-1200
Percent flowers opened[a]	5	30.1	90.0	100.0(53)[b]							
	6	25.3	46.4	100.0(71)							
	10	30.8	75.0	100.0(68)							
Mean volume of nectar per covered flower - in µl	5						0.81	0.41	0.42	0.26	0.18
	6					0.26	0.46	0.22	0.39	0.26	0.16
	10						0.36	0.42	0.36	0.25	0.01
Mean percent soluble solids	5						38.0	37.3	31.6	28.4	33.8
	6					38.0	37.4	40.3	31.3	34.0	35.7
	10						38.0	36.2	33.0	30.5	38.0
Mean volume of nectar per uncovered flower in µl.	5						0.0	0.02	0.13	0.0	0.16
	6					0.16	0.08	0.0	0.06	0.0(+)	0.0
	10						0.01	0.12	0.0(+)	0.0(+)	0.0(+)

Table VII.--Continued

	July	Hours 0700-0730	0730-0800	0800-0830	0830-0900	0900-0930	0930-1000	1000-1030	1030-1100	1100-1130	1130-1200
Mean percent soluble solids	5						-	38.0	33.0	-	34.0
	6					36.0	34.0	-	33.3	-	-
	10						-	37.0	-	-	-
Mean number of bees per flower	5	1.25	0.18	0.13	0.14	0.08	0.04	0.03	0.06	0.03	0.0
	6	0.16	0.09	0.16	0.15	0.07	0.06	0.06	0.03	0.03	0.02
	10	0.20	0.06	0.02	0.08	0.06	0.06	0.06	0.03	0.01	0.001
Range	5	4.0	3.0	5.0	10.0	6.0	3.0	0.0	3.0	2.0	0.0
	6	1.0	8.0	1.0	10.0	5.0	5.0	3.0	1.0	1.0	1.0
	10	7.0	5.0	0.0	2.0	3.0	1.0	3.0	1.0	1.0	1.0

a) Sunrise 0522 hours on July 5-6, and 0523 hours July 10.

b) Total number of flowers for 50 ft. of row for that day.

Table VIII.--Mean percent of soluble solids in samples taken from bee honey stomachs. Tucson, Arizona. July 1967.

	July 4				
	0930-1000	1000-1030	1030-1100	1100-1130	1130-1200
No. Bees Sampled	10	8	10	4	6
Mean Percent Soluble Solids	36.0	34.0	34.0	30.0	34.0

c) Pollen determination. It was necessary to be absolutely certain that those bees seen collecting pollen were in fact collecting watermelon pollen. Slide preparations were made of (1) pollen taken from the anthers of several staminate flowers, (2) pollen grains from the corbicular pellets on bees observed actually working the flowers, and (3) pollen grains from corbicular pellets on bees entering a nearby hive.

The slide preparations were made using a modified, basic fuchsin-gelatin stain originally suggested by Wodehouse (1935).

Results of the comparison of the anther samples with the corbicular samples are described in the Results and Discussion section of this paper. Photomicrographs of the pollen study are shown in Figures 7, 8, and 9.

d) Other pollinators. The numbers and families of other potential pollinator insects represented were determined. Observations were made for possible relationships to the population of honey bee foragers.

During the 1966 field test, wild pollinators were very scarce. The few wild bees observed during five weeks of studies did not seem to warrant any attention other than identification and a few observations.

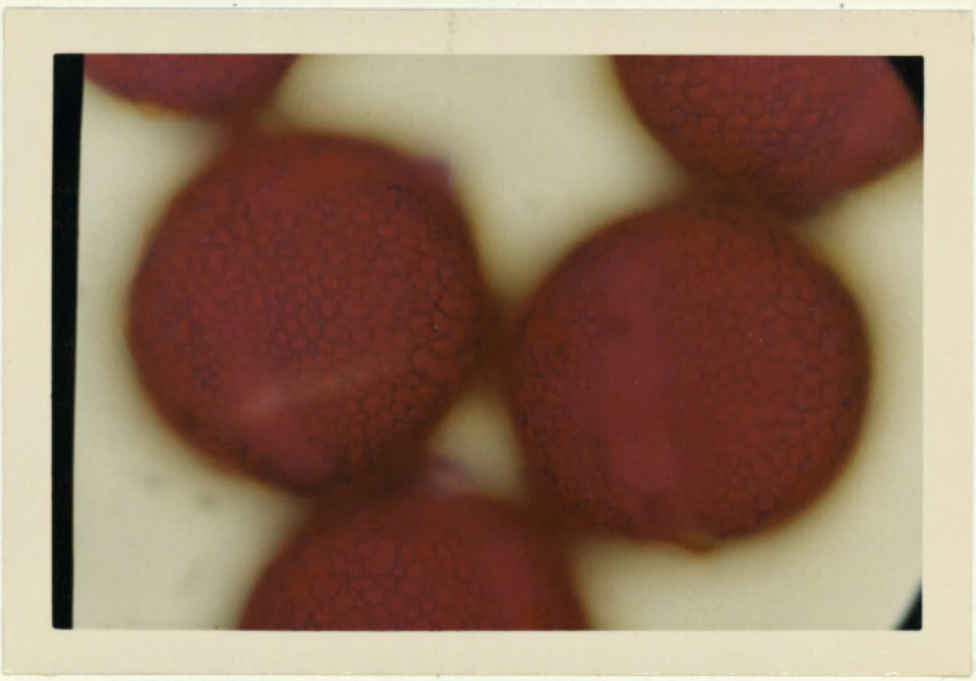

Figure 7. Photomicrograph of pollen grains removed from the anther surfaces of a staminate Peacock flower

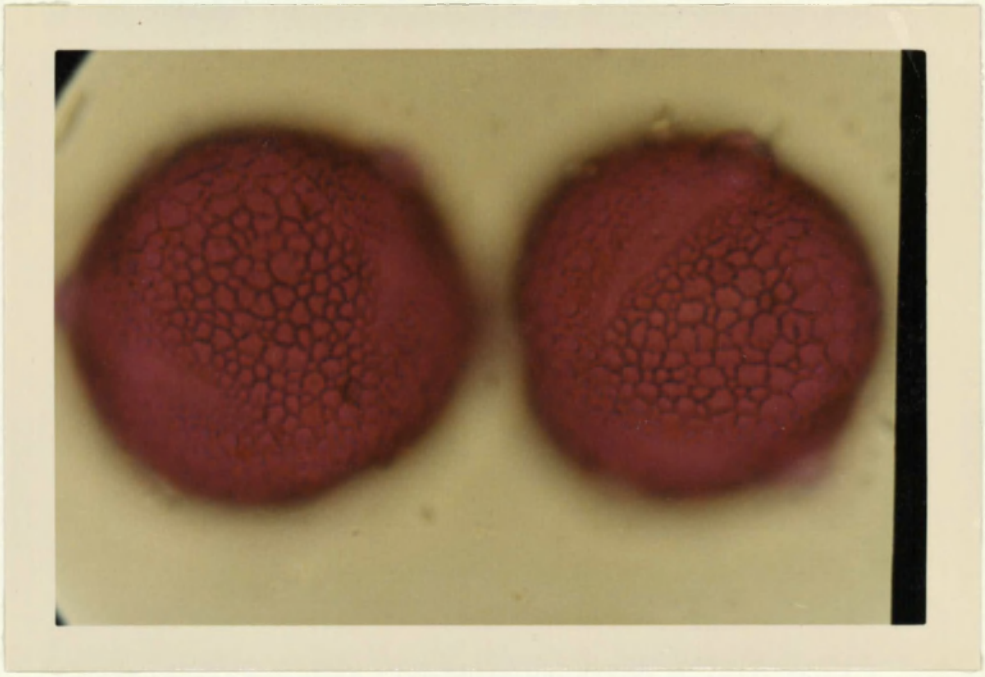

Figure 8. Photomicrograph of pollen grains from a corbicular pellet removed from a honey bee collecting pollen on a staminate Peacock flower

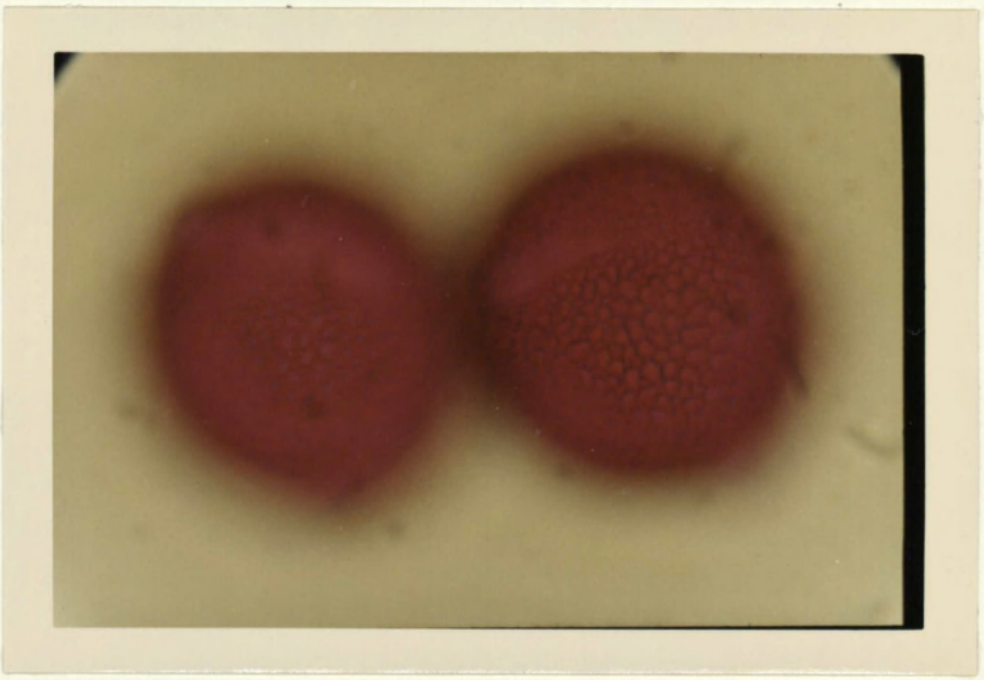

Figure 9. Photomicrograph of pollen grains from a corbicular pellet removed from a honey bee at the entrance to a nearby hive

In 1967, however, wild bees were much more abundant and were given greater consideration. Details of the 1967 observations are also included under Results and Discussion.

e) Environmental factors. Temperature and humidity records were kept on all test days. All test days were bright and cloudless except for one, noted in the Results and Discussion section, and the temperature during the foraging periods was above 75 degrees with variable humidity and no strong winds. In the author's opinion, the treatment of temperature should be an entirely separate investigation wherein climates in the hive, at the hive entrance, in the flight path, and especially the micro-climates amongst the leaves and flowers of the crop involved should all be accurately measured.

f) Miscellaneous observations. A few brief observations that were made in conjunction with the tests described above are also recorded in the Results and Discussion section.

RESULTS AND DISCUSSION

Floral Observations

a) Time of anthesis. Tables I and II present the time of anthesis data for 1966 and 1967. In both years the two lines showed the same tendency for anthesis to occur earlier as the time after irrigation increased. On the fifth and sixth days (June 22-23) after irrigation in the 1966 test, the time of anthesis was the earliest with 100% of the Peacock blossoms opening on June 23 by 0800, approximately two and one-half hours after sunrise. In the 1967 test, the blossoms opened earliest on the sixth day (June 16) after irrigation when 97.0% of the flowers had opened by 0800, approximately two hours and 45 minutes after sunrise. The times in the 1967 test are based on daylight saving time, whereas, those in 1966 are mountain standard times. The discrepancy in the times at which the flowers opened each year can only be explained by the fact that there were large cages on the sunrise side of the plot in 1966 and the plot was in shade for about 20-30 minutes after sunrise.

The data collected from the male sterile line cannot be relied upon too heavily because the numbers of flowers involved were very small, not exceeding 12 flowers on any given day. The male sterile line data do seem, however, to demonstrate the same earlier anthesis related to increasing time after irrigation date.

The criterion used to determine open flowers was established by the bees themselves; if the bee could enter, the flower was considered open. Bees were always searching over the plants before anthesis, often as early as 0500. At least 70% of the flowers were open by 0800, but in June no flowers during this period opened before 0650. It was important to have the latter information so that population counts and behavioral investigations might be undertaken at the proper times. It was equally important to note the time at which the flowers closed.

At the outset of the behavior investigations it was not known whether bees would forage on the flowers the entire time they were open. The time of closing was determined in the same way the time of anthesis was studied.

Anthesis in Peacock flowers occurred during periods extending from 30 minutes to over an hour

(Table II, June 17). Closing of the Peacock flowers, however, took a longer time, from 60 minutes (Table IV, June 13) to 80 minutes (Tables III and IV). It was noted on several days during both seasons that the reflexing of the petals actually began as early as 1100; final closure, however, would not usually occur until 1400-1430.

All flowers were closed by 1430 on all test days. Flowers were considered closed when the petals had obviously reflexed enough to prevent a bee from entering the flower. Native bees were seen flying over the watermelon plants after closure but were never observed forcing an entry into a closed flower.

Although data are far from conclusive, there seems to be a tendency for the flowers to close earlier as the time increases after an irrigation.

b) Anther dehiscence. After the times of anthesis and closing were determined, the times of anther dehiscence and pollen availability were studied. The detailed mechanism of pollen presentation was not considered; I wanted, rather, to learn whether the anthers actually dehisced and if pollen was available to the bees when anthesis occurred. Table V indicates that in 50 flowers opened with forceps on two out of three mornings, all three anthers had dehisced, and the

sticky watermelon pollen would adhere at the slightest touch to a piece of clean white paper. On one morning, however, two staminate flowers out of 25 bore anthers that had not dehisced. Due to the unnatural technique of forcing the flowers open with forceps, it was not possible to determine whether the anthers later dehisced.

Tables I and II show that the Peacock flowers do not open before 0650; pollen, however, is available to the bees as soon as the flowers open.

c) Nectar secretion. Nectar secretion was investigated after the times of anthesis, flower closing, and anther dehiscence had been determined. My observations sought to answer the question: how early does nectar secretion begin? It was found in preliminary tests in 1966 that only 20 flowers could be sampled by one person in a half hour. Therefore, the mean amounts of nectar are based on only 10 flowers in each line.

The results from July 19, 1967, show that nectar secretion did not begin until at least 0900, more than two hours after anthesis. The peak amount of nectar was collected from both lines each day at 1000 to 1030 hours. No difference was detected in time of nectar secretion in pistillate and staminate flowers

although this was difficult to determine in the male sterile line because of the scarcity of male flowers. Taking into account the fact that the microliter syringe does not remove all of the nectar, plus the probable reduction of the aqueous fraction of the nectar, the data presented in Table VI should be considered only as mean amounts collected, not necessarily the amount secreted.

Samples of nectar could be taken after 1200, but this information was not recorded because no honey bees were found foraging in the flowers after that time.

Although a two-day study cannot determine finite relationships between irrigation and nectar secretion, the data in Table VI indicate earlier secretion occurs as the effect of irrigation decreases.

Bee-Flower Relationships

a) Individual behavior. Honey bees visiting various crops for food can be generally divided into two groups: those that will collect only nectar, and those that gather pollen. Often there will be two separate populations working on the same crop at the same time for different purposes. Levin and Butler (1966) recently demonstrated this on safflower (*Carthamus tinctorius* L.) where two distinct sets of honey

bee foragers were working on the flowers, one collecting nectar and the other gathering pollen. Both populations commenced foraging before 0700 and both worked until 1600, but the nectar collectors reached a peak at approximately 0900, whereas, the pollen collectors reached a peak at 1000 hours, almost disappearing shortly after 1300.

Because nectar secretion in the Peacock and the male sterile line cultivars occurred considerably later than pollen presentation, detailed observations were made to determine activity between 0700 and 0900, when pollen was available, and between 0900 and 1200, the period of nectar secretion.

Figure 5 shows a honey bee during the pollen-gathering period in what can be called the "preliminary stance." With few exceptions, the bee would always take this frons-to-anther position upon alighting. The bee would then extend her proboscis forward and insert it into the nectary area between the bases of the filaments.

After very rapidly removing her proboscis, the bee would twist about and place herself in the "terminal stance" (shown in Fig. 6). In this venter-to-anther position, the bee would reach down between the lower curve of the anther surfaces and the base of the petals

-- the corolla -- and again extend her proboscis into the nectary area. In this position, however, the forager would have to retract her proboscis over the convoluted surfaces of the anthers and in so doing her proboscis would become covered with pollen. In every observation, the bee would then leave the flower and hover about one to two inches away. In this hovering position, the bee would again extend her proboscis and stroke it with her clistal, front legs. From the front legs the pollen was quickly transferred to the pollen "combs" on the inside of the hind legs. The "rubbing" together of the hind basitarsi was clearly visible, and the bee was still packing pollen into the tibial corbicula as she again approached the same flower. The second approach, however, was unlike the first in that the "terminal stance" rather than the preliminary was assumed upon alighting. The action of the proboscis was then repeated.

In several observations the forager would probe two or sometimes all three nectary "entrances" before lifting off and packing the pollen.

Another repetitious pattern involving antennal movements was recorded during the observations. In every instance, upon approach to the flower (two to six inches away), the antennae would be spread noticeably

apart and held at almost a right angle to the frons. As the bee approached within one inch of the flower, her antennae would come very close together and would be directed downward (approximately 30 degrees lower than the right-angle position) toward the flower. This same characteristic antennal movement took place if the bee hovered more than an inch away to pack the pollen it had collected.

The two behavioral stances just described -- preliminary and terminal -- together with the characteristic antennal and proboscis positions were found not only during the pollen-gathering period but also during the nectar-collecting period. Honey bees were seen to collect pollen from time of anthesis until bees were no longer observed in the field. No characteristic behavior patterns other than those described were noted during the period of nectar secretion. No differences in behavior could be detected between nectar collectors and pollen collectors.

Honey bees working pistillate flowers from 0700 to 0900 assumed both positions shown in Figures 5 and 6. However, on all test days there were very few bees on the pistillate flowers until nectar secretion began.

The observations in 1966 revealed that nectar collectors on pistillate flowers during the secretion period seemed to favor the preliminary position over the terminal stance. In the more detailed study in 1967, however, this difference did not exist. Out of 10 separate observations of 50 bee visits to 10 female flowers, 43 bees assumed both stances while on the blossoms. Honey bees working the male sterile line flowers behaved in the same way as those on Peacock flowers.

The descriptions of the proboscis movements during pollen collection as described above are reported in the literature in connection with observations made on bees collecting nectar by Park (1949) and Haydak (1963). The observations of the proboscis movements of these foraging bees raise some interesting questions. Are the bees demonstrating the proboscis manipulations, described above, primarily in search of nectar and collecting pollen only secondarily? Are the extended proboscises gathering some rewarding "nectar factor," which is so minute in quantity that it cannot be detected either by microliter withdrawal or visual inspection, or does the honey bee working the staminate flowers of Citrullus lanatus actually use the proboscis primarily as a pollen-gathering tool?

In 1966, studies were made on a cucumber (Cucumis sativus) crop. Bee behavior on this cucurbit crop was both comparable and in contrast to that described for watermelons. The cucumber crop was a 70-acre planting of S M R 58 at Amado, Arizona. This cultivar was monoecious and usually bore two pistillate flowers at the nodes of its secondary branches. The staminate flowers were almost always found in groups of five flowers, but a few groups observed contained only three staminate blossoms.

On the two days of the observations, the honey bee foragers would be over the crop as early as 0600, even though the flowers would not fully open before 0630. Pollen of this cucumber, as in the watermelon cultivar, was available at anthesis, and the first honey bees found in the field were pollen collectors. Upon alighting on a staminate flower, the pollen collector assumed a position that was very much like the preliminary stance of foragers on Peacock watermelons. The bee, however, did not immediately extend its proboscis but walked to the center of the flower and there uncurled the mouthparts. The cucumber flower, being smaller than that of watermelon, has a corolla base that is tubular and contains the sexual parts. The anthers of the staminate flower could barely be seen

at the opening to this tube. The bee, because of the flower's structure, literally stood on its head to probe for nectar and pollen. The hind legs were fully extended with the anterior-posterior axis being almost in a vertical position. It was observed that the bees that worked the pistillate flowers also assumed this position although the stance did change somewhat from observation to observation.

What was most interesting, however, was that the proboscis was always inserted whether nectar was available or not. Nectar secretion began about 0900, which was comparable to that in watermelon. From 0630 until 0900 the proboscis movements were part of the foraging behavior of the individual bees. Pollen was collected during this time, and the packing behavior was similar to that of bees on watermelon. The bee would either return to the same flower or go to another.

The shape of the cucumber flower is such that the proboscis becomes a tool for pollen collection as well as nectar collection. In watermelons, however, the anthers are fully exposed and available for pollen collection without the proboscis movements described above.

Free (1964) describes bees "scrabbling" (a leg movement) for pollen on sunflowers. Mandibles are

also used to collect pollen, Haydak (1963). Regurgitated honey or nectar would not be needed to help form a pellet of watermelon pollen because it is already very sticky (Hodges, 1952). It is difficult to explain the behavior of honey bees on the staminate watermelon flower unless the movements are defined as adaptive behavior peculiar to watermelon pollen foragers.

Observations made on a small plot of PMR-45 cantaloupes (Cucumis melo) at Tucson, Arizona, also provided some comparisons. Nectar secretion began at 1030; however, measurable amounts were not available until about 1100. At this time, rough estimates of foragers indicated a slight increase in population until about noon. Thirteen bees were squeezed for honey stomach samples, and a mean 34.6% soluble solids was recorded for the 4-hour period prior to nectar secretion of the flowers. From 1030 to 1230, bees were sampled for percent soluble solids, and the mean % had risen to 38.1. Of 10 flowers sampled during this period, 40.6 was the mean % of soluble solids.

Behavior during the period of nectar collecting (1030-1230) was different from that displayed during pollen collection. The nectar collectors would alight and walk as far as possible down into the campanulate flower and insert the proboscis into the

tube formed at the base of the petals. The bee would then walk sideways while the proboscis was still in contact with the flower and make almost a complete circle about the blossom center. In 10 observations, the length of time spent on the flower ranged from 5.9 to 12.1 seconds and the average time was 10.4 seconds. Pollen collectors spent an average of 7.9 seconds on each flower. Upon withdrawing the proboscis, the bee would hover above the petals and stroke off any pollen on the mouthparts and then pack the pollen in the corbicula.

Pollen in this PMR-45 cultivar was available to the bees by 0830; however, in both the staminate and hermaphroditic flowers, the sexual structures are sheathed in the tube formed by the petal bases. Again, as in the behavior displayed by bees on cucumber flowers, the pollen collector is forced to make use of the proboscis as a pollen-gathering tool. On the cantaloupe flowers the bee would insert the proboscis, but upon withdrawal, the pollen would mostly be on the middle portion of the proboscis. Only a few pollen collectors were seen to brush over the face and mandibular area after proboscis withdrawal. The characteristic stroking previously mentioned was again used to remove the pollen from the proboscis. The fact that little

pollen was noticed on the lower portion of the proboscis might indicate that the bee was first of all searching for nectar. The pollen would collect on the proboscis at the height described if the mouthparts were inserted all the way down to the nectary area. This assumption was tested by inserting the microliter syringe into the tubular flower down to the nectaries and then withdrawing it. Pollen on the needle collected in very small amounts at a height comparable to that observed on the bee's proboscis.

It was previously mentioned that the bee is forced to use its tongue as a pollen-collecting tool in both cantaloupe and cucumber. The fact remains, however, that this does not appear to be the case in watermelon. In cucumbers the bees collect primarily pollen and nectar and in cantaloupes primarily nectar although pollen is also collected. Honey bees on watermelon seem to be primarily pollen collectors, and it can be postulated that their proboscis movements are adapted for collecting pollen from the staminate flowers of watermelon blossoms.

b) Nectar, pollen and bee visitation. In order to further explore the relationship between the behavior of the bees and the floral factors, bees were counted when times of anthesis and nectar secretion were

recorded. The nectar samples were measured and percent soluble solids determined. Observations were also made on the details of the foraging movements of individual honey bees. The data are presented in Table VII. The peak honey bee population was reached before 0900. Although nectar was available at 0900, the peak period of secretion was between 0930 and 1030. On all days except July 10 the population definitely began to fall off before the peak nectar secretion period was reached. Percent soluble solids was highest from 0900 to 1100 hours.

The average number of bees per flower indicated that the population peak appeared to be more closely related to pollen collection than nectar collection. This conclusion was supported by the observations on individual bees which collected pollen in the manner described earlier until 0900 to 0930 hours. During the nectar-secretion period, the bees seemed to increase the average duration of visits on a flower. The withdrawal of the proboscis, which previously was almost instantaneous after full extension, was considerably slower during the first hour of nectar secretion. The few bees present during this period were very likely collecting nectar in addition to pollen, but there was not another definable "nectar collector"

population. It is important to note that a fairly large wild bee population was also gathering nectar in the uncovered flowers used in the sample. The fact that wild bee foragers were also present during the observations might account for the 0.0 figures for nectar secretion in the uncovered flowers at 1030 and 1130 hours.

The mean percent soluble solid figures shown in Table VIII exhibit almost the same pattern as the percent of soluble solids in covered and uncovered flowers in Table VII, except that Table VIII displays a definite decrease in percent soluble solids at the 1100-1130 period. No explanation is offered for this decrease in percent soluble solids in the foragers' honey stomachs. Samples were taken from pollen collectors at 0800, and in the 10 bees sampled, the percent soluble solids was 38.0%, a figure not greatly different from those listed for bees collecting nectar at 0930-1000 hours (Table VIII). The fact that bees often bring honey from the hive to work into the pollen collected (Hodges, op. cit.) makes it very difficult to see a relationship between percent soluble solids in the flowers and the same factor in the bee's honey stomach.

Another observation was made which tends to support the idea that bees on Peacock watermelons

are primarily collecting the pollen. At 1200 hours, when nectar was still available, on July 5 and 10 almost no bees were found in the flowers.

c) Pollen determination. It was possible that the pollen seen in the corbiculae of foragers during the nectar secretion period was not watermelon pollen. To determine if this was so, bees were caught between 0900 and 1000 hours, their pollen pellets were removed and subjected to microscopic comparison of pollen removed from Peacock anthers and photomicrographs in Zander (1937).

Figures 7, 8, and 9 show that honey bees collected during foraging flights in the nectar-secretion period were indeed gathering cucurbit pollen. The grains from the corbiculae (Figures 8 and 9) compare quite closely with those removed from the anthers (Figure 7).

d) Other pollinators. A very brief survey and some observations were made on the behavior of other insects commonly found on the flowers. The insects listed had, in the author's opinion, some influence in 1967 on pollination one seemed numerous enough to be a "major" pollination factor and that was a native bee of the family Halictidae. It was small enough so that it could walk around the whole anther surface and also

about the base of the stamens. Its presence in the flowers often seemed to prevent some honey bees from alighting on the flowers, although both bees were just as often observed on the flowers together.

Pollen was found in various amounts on representatives of the following families: Chrysomelidae (Coleoptera), Hesperiidae (Lepidoptera), Syrphidae (Diptera), Apidae, genus Bombus (Hymenoptera), and Megachilidae (Hymenoptera). However, no effort was made to compare this quantitatively with pollen removed by honey bees.

A cucumber beetle was noted on two different occasions to be working over the anthers with its mandibles; however, no particular damage to the anthers was noted, and it could not be discovered if the beetle was in fact eating the watermelon pollen.

e) Miscellaneous observations. Repeating work already done by Adlerz (op. cit.) on the Charleston Gray cultivar, the number of visits necessary to set a melon that will grow to maturity was calculated for Peacock.

The data listed in Table IX are on the first flowers, and the results are not strictly comparable to Adlerz' work due to the smaller number of observations. The percent fruit set at six visits appears to

Table IX.--Effect of bee visit numbers on fruit set in Peacock watermelon. Tucson, Arizona. 1966.

No. of bee visits per flower	Percent fruit set	
	June 24	June 25
0	0.0	0.0
1	0.0	0.0[a]
2	10.0	0.0
4	20.0	10.0
6	60.0	30.0
8	40.0	30.0
10	30.0	40.0
12	20.0	60.0
14	-	80.0

a. One ovary appeared to set, and developed larger in size for five days, turned dark, and dropped.

be the critical number necessary for a third of the first flowers to set and reach maturity. The decrease in fruit set percentages listed (Table IX) after six visits on June 24 may be due to competition from other set melons on the plant. I cannot, however, fully explain this decrease on the basis of data collected at this time. Observations made in 1966 on the number of bee visits per half hour always showed that at least eight visits were made to all pistillate flowers observed during the hours of 0730 to 0930. At the population level of the test plot, all blossoms that theoretically might set would receive adequate numbers of bee visits.

In 1966 several varieties of honeydew melons (Cucumis melo L.) were planted at the ends of the rows of watermelons. During the field observations no bees working down the rows of watermelon plants were seen to continue into the honeydew flowers. In 1967, however, the PMR-45 cantaloupe was planted at the ends of the watermelon rows with a 50-60 foot interval between the last Peacock and the first cantaloupe plant. On four occasions during the pollen-collecting period of the bees on Peacock watermelons (0650-0900), four bees (one at each observation) were seen moving

from staminate Peacock watermelon flowers to cantaloupe flowers, both staminate and hermaphroditic.

Bateman (1951) and Ribbands (1949) both report bees working two crops on the same foraging trip; this is not, however, a common behavioral pattern in honey bees.

SUMMARY AND CONCLUSIONS

The conditions discussed in this paper affecting the foraging behavior of the honey bee are limited to biotic factors. The most influential factor is the time of anthesis and pollen availability. Population counts and related observations indicate a relatively high pollen collector population on watermelon. Those bees that seem to be collecting nectar in addition to pollen are few in number.

The unusual manipulations of the proboscis by the bee during the pollen-collecting period are difficult to explain in view of the lack of detectible amounts of nectar in the flowers. It appears that the bees are using the proboscis as a pollen-collecting tool.

On the watermelon cultivar Peacock and the male sterile line it is concluded that:

1. The honey bee is the main pollinator of these lines in the area studied.

2. Foraging behavior of honey bees on many crops may be cyclic, that is, two separate and discernible foraging populations can be distinguished. Only

one population in this experiment was clearly definable -- the pollen collectors. Although nectar collectors could not be identified, nectar collection was taking place. This was evidenced by the small amounts of nectar found in uncovered flowers compared to larger amounts accumulating in covered flowers during the nectar secretion period. Wild bees may also have been removing nectar during this time.

3. On watermelon the honey bee clearly uses its proboscis to help collect pollen. On cantaloupe and cucumber the flower shape dictates to a certain extent the obligatory use of the proboscis as a pollen and nectar collection tool. The behavior of foragers on watermelon indicates an initial probe for nectar, after which the proboscis, in the terminal stance, is always retracted over the anther surfaces to become coated with pollen.

4. The flowers, and the times at which they open, seem to be related to the drying of the soil. This characteristic needs further investigation and may be related to temperature although the temperatures of the test mornings were about the same at anthesis. Total sunlight is another factor that may be independently related to flower opening or may be an adjunct to temperature.

5. The fact that foragers are not found in the field after 1200 should be explored further. Temperature charts kept in 1967 indicate that the temperature at 1200 ranged from 98° F to 105° F, whereas, temperatures at the peak foraging period were always between 92° F and 95° F. Although nectar could still be found in the Peacock watermelon flowers after 1200, the highest number of bees on the same test days were found in cantaloupe from 1200 until 1330. The nectar in the cantaloupe flowers may be more attractive than that in watermelon blossoms.

6. Six visits to the first pistillate flowers seem to be sufficient to set a melon that will grow to maturity. The above experiment was conducted on a small sample and without regard to ovary length. Adlerz (op. cit.) demonstrates that ovary length is important to fruit set, and the experiment on Peacock should be repeated to include this factor.

7. Honey bees visiting staminate watermelon flowers have been observed visiting both staminate and hermaphroditic flowers of cantaloupe on the same foraging trip.

8. A few native bees are effecting a small amount of pollen distribution in Peacock flowers and should be further investigated to see if they can actually set melons.

9. Since almost all bee activity takes place while flowers are open, and this is generally from 0650 to 1430, applications of low-residue pesticides can be made with relative safety in the late afternoon or early evenings.

The data presented in this study are important to an understanding of what the bees actually do on the flowers and what biotic factors have the greatest effect on their foraging behavior. Basic research on pollen odor and antennal reception should be conducted as well as more detailed studies of floral physiology.

REFERENCES CITED

Adlerz, Warren C. 1966. Honey bee visit numbers and watermelon pollination. J. Econ. Entomol. 59(1): 28-30.

Bateman, A. J. 1951. The taxonomic discrimination of bees. Heredity 5: 271-278.

Goff, C. C. 1937. Importance of bees in the production of watermelons. Fla. Entomologist 20(2): 30-31.

Haydak, M. H. 1963. Activities of honey bees. Chapter IV in Roy A. Grout (Ed.) The hive and the honeybee. Dadant and Sons, Illinois. 556 pp.

Hodges, Dorothy. 1952. The pollen loads of the honeybee. Bee Research Assoc., Ltd., England, 51 pp.

Jones, H. A., and J. T. Rosa. 1928. Truck crop plants. McGraw-Hill Co., New York. 538 pp. (citation: pp. 465-466).

Levin, M. D., and G. D. Butler, Jr. 1966. Bees associated with safflower in South Central Arizona. J. Econ. Entomol. 59(3): 654-657.

Park, O. W. 1949. Activities of honey bees. Chapter IV in Roy A. Grout (Ed.) The hive and the honeybee. Dadant and Sons, Illinois. 652 pp.

Percival, M. S. 1955. The presentation of pollen in certain angiosperms and its collection by Apis mellifera. Phytologist 54(3): 353-368.

_____. 1965. Floral biology. Pergamon Press, Oxford, England. 243 pp.

Ribbands, C. R. 1949. The foraging method of individual honeybees. J. Animal Ecology 18: 47-66.

Ribbands, C. R. 1951. Flight range of honey bee. J. Animal Ecol. 20: 220-226.

Rosa, J. T. 1925. Fruiting habit and pollination of the watermelon. Proc. Amer. Soc. Hort. Sci. 22: 331-333.

Whitaker, T. W., and Glen N. Davis. 1962. Cucurbits. Interscience Publishers, Inc., New York. 250 pp.

Wodehouse, R. P. 1935. Pollen grains - their structure, identification, and significance in science and medicine. McGraw-Hill Co., New York. 574 pp.

Zander, E. 1937. Beitrage zur Herkunftsbestimmung bei Honig. Vol. II. Verlag Liedloff, Loth & Michaelis. Leipzig. 122 pp.