RELATIONSHIP OF SOME WEATHER FACTORS TO THE HONEYFLOW

by

JOSEPH ORR MOFFETT, JR.

B. S., Kansas State College
of Agriculture and Applied Science, 1949

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Entomology

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1950

TABLE OF CONTENTS

INTRODUCTION

There are many interacting and related factors which influence the amount of honey produced by a colony of bees. The differences in yield in individual colonies in the same apiary are due usually to causes within the colony, such as insufficient bees, poor queen, insufficient space for brood rearing and honey storage, poor comb in which to rear brood, individual differences in bees, and many other causes. However, the wide differences in the amount of honey stored in different years in the same apiary operated by the same person can hardly be accounted for by internal variations in the colonies alone.

Demuth (1912) stated there were four main factors necessary for a good honey crop: overpopulous colonies at the time of the honeyflow, which is nectar secretion by flowering plants collected by honeybees in surplus quantities; maintenance of the storing instinct dominant over the swarming instinct; honey plants in optimum condition; and suitable weather for nectar secretion and its collection by the bees.

The first two of these factors, overpopulous colonies at the time of the honeyflow and the maintenance of the storing instinct dominant over the swarming instinct, have been studied by various workers in great detail, probably because they could be controlled partially by the beekeeper. The last two have been studied far less completely. In some localities the third factor, the condition of the honey plants, can be controlled partially by irrigation and other practices, such as the use of later or earlier maturing varieties of plants, resistant varieties, and improved agricultural policies. Also, honey plants which tend to reach an optimum condition for nectar secretion at a favorable time to store surplus honey can be planted in waste places in localities where they would thrive. Little can be done at the present time to control the weather factors in most areas, although plants can be supplied with much needed moisture at crucial times in irrigated regions.

This study is an attempt to find the relationship between certain weather factors and the amount of surplus honey stored by colonies of honeybees at Manhattan, Kansas. Somewhat similar studies have been made in Iowa by Kenoyer (1917a, 1917b), in Manitoba by Mitchener (1927) and by Braun (1945), and in Michigan by Jorgensen and Markham (1946). No similar report has been made for Kansas.

The important honey plants of this area are yellow sweet clover, (Melilotus officinalis), white sweet clover, (Melilotus alba), alfalfa, (Medicago sativa), and smartweed, (Polygonum spp.). Many minor plants, such as dandelion, (Taraxacum officinale), basswood, (Tilia americana), white clover, (Trifolium repens), soft maple, (Acer saccharinum), and fruit trees, furnish important sources of nectar for shorter periods, or at times needed for feeding brood during the increase of colony populations. The nectar from these minor plants is important in helping to maintain the colonies during the periods when nectar is unavailable from the main honey plants. While little or no surplus may be stored from minor plants during their blooming period, the colonies may maintain themselves on this nectar, thereby not depleting the honey they have stored.

REVIEW OF LITERATURE

Factors which influence nectar secretion do not cause similar changes in colony weights (Hambleton, 1925). Plants must secrete nectar, however, before the bees can gather it. Therefore, some of the ways in which weather conditions affect nectar secretion are given in the following reviews, as well as the effect of weather conditions on the actual gathering of nectar by the bees.

Lovell (1924) stated that temperature exerts a greater influence than light, humidity, or rainfall on nectar secretion. He stated that high temperatures favor nectar secretion in three ways, (1) the solvent power of water is increased, (2) the membranes of the nectary are rendered more permeable, and (3) the chemical changes in the plant take place more readily. He stated further that excessively high temperatures may be injurious to the plant. Kenoyer (1917b) also stated that excessively high temperatures may be injurious to the plant. He found that the secretion rate of both sugar and water increased with higher temperatures up to a certain optimum, and the accumulation of sugar in the flower varied inversely with the temperature. Oertel (1946) found that during some seasons, there was a significant, positive correlation between temperature and sugar concentration of the nectar, while in other seasons undetermined factors influenced the sugar concentration of the nectar. Beutler (1934) stated that air temperatures, within the biological limits, did not affect the nectar flow in her experiments.

Lovell (1924) stated that individual plants varied greatly at the temperature at which they begin to secrete nectar. According to Lovell (1924) sweet clover yielded best between 80 and 90 degrees F.; sainfoin yielded best between 60 and 65 degrees F., while bees have been observed to work heather in England with the temperature between 48 and 52 degrees F. Demuth (1923) stated that basswood began to yield nectar at 64 degrees F. Vansell (1940) found that warm temperatures were favorable for nectar secretion in poinsettias. Vansell (1941) stated that continuous warmth resulted in maximum secretion under greenhouse conditions.

Jorgensen and Markham (1946) found that a fall, winter, and spring of above normal temperature usually preceded a good honeyflow, while a below normal temperature for these same periods usually preceded a poor honeyflow. Kenoyer (1917a) stated that a slightly higher than average temperature during the honeyflow, particularly during the spring and fall months, was favorable for a good honeyflow. He found that a cold winter was not detrimental to the following season's honeycrop, but a cold March definitely reduced the honeyflow.

Kenoyer (1917a) and Jorgensen and Markham (1946) stated that a maximum daily temperature between 80 and 90 degrees F. during June and July was the most favorable temperature for a good honeyflow. Kenoyer (1917a), Hambleton (1925), and Mitchener (1927) stated that a wide daily range of temperatures was favorable for a good honeycrop. Braun (1945) found no correlation between maximum and minimum temperatures and the daily honeyflow. Mitchener (1927) stated that the higher the maximum temperature, the greater the honeyflow in Manitoba. In places closer to the equator this apparently is not true, as Kenoyer (1917a) and Lovell (1924) stated that excessively high temperatures--over 95 or 100 degrees F.--greatly decreased the honeyflow. Lundie (1925) stated that on excessively hot days there were few flights of bees, while the lowest temperature at which flight was observed during the honeyflow was at 50 degrees F.

Lovell (1924) stated that rainfall affected honey production by its influence on the growth of the plant, the development of the flowers, and the secretion of nectar. Lundie (1925) pointed out that storms and rain decreased the bee flights. Kenoyer (1917b) and Lovell (1924) stated that in open wheel-shaped flowers the nectar may be diluted or washed away by artificial water spray. Rains would have an effect similar to this artificial water spray on open wheel-shaped flowers, either diluting or washing away the nectar.

Kenoyer (1917b), Lovell (1924), and Jorgensen and Markham (1946) stated that a good honey production season was preceded by a year of above average precipitation. Lovell (1924) stated that a wet preceding fall was favorable for a good honeyflow, while a dry preceding fall was unfavorable for a good honeyflow. Kenoyer (1917a) found that a good year was preceded by a fall and spring of above average precipitation, a May with abundant rainfall being particularly favorable. Munro (1929) and Jorgensen and Markham (1946) stated that excessive rainfall during the normal nectar secretion period greatly reduced the honeyflow. However, Braun (1945) found no evident correlation between precipitation and the daily honeyflow.

Kenoyer (1917a) and Dalton (1931) stated that a rain in the midst of a honeyflow depressed the flow for about three days. Lovell (1924) pointed out that sometimes a cold rain, accompanied by a sudden drop in temperature, brought to an abrupt end the honeyflow for that year.

Kenoyer (1917a) reported that a heavy snowfall the preceding year was decidedly beneficial to the honey yield. Jorgensen and Markham (1946) found that a good snow cover during January was beneficial, otherwise the amount of snowfall had little influence on the honey crop of next summer. If the ground was covered with snow during the coldest part of the winter, it probably helped to prevent the plant (white clover) from heaving. Therefore, the plant was in better condition in the spring, and the better the condition of the plant, the more nectar it secreted.

Kenoyer (1917b) and Lovell (1924) stated that if the relative humidity is high, more water passes through the nectaries, but the amount of sugar remains constant. They also stated that if the relative humidity is high, there is a decrease in the sugar content of the nectar. Park (1929) pointed out that the sugar content of the nectar varies inversely with the relative humidity.

Oertel (1946) found a significant negative linear correlation between relative humidity and the sugar concentration of nectar during some seasons, but in others he was unable to find a significant correlation between the relative humidity and the sugar concentration of the nectar. Many bee culture investigators consider that cool nights and warm days favor nectar secretion. This may be because when there are cool nights and warm days, the relative humidity also varies greatly. Littlefield (1941) stated that cooling plants at night and warming them in the daytime did not increase the nectar secretion of the plants when the humidity was controlled artificially. Beutler (1934) stated that high humidity was found to dilute the nectar through hygroscopic absorption, but soil moisture had little or no influence on its concentration. Vansell (1941) stated that the sugar concentration of nectar is increased by the lowering of the soil moisture and relative humidity. Vansell (1940) found that if soil moisture was withheld from poinsettias, nectar secretion was greatly reduced, but nectar secretion continued even if wilting occurred.

Hambleton (1925) found a correlation of +0.4229 between daily net gains and the daily variation of relative humidity, as well as a correlation of -0.3806 between daily net gains and the average relative humidity. A perfect correlation between two factors would be 1.000. If one factor decreased when the other factor decreased, and they both increased together, a perfect correlation for these two factors would be 1.000. If one factor usually decreased when the other factor increased and vice versa, a perfect correlation would be -1.000. If there is no correlation between two factors, they would have a theoretical correlation of 0.000. In readings taken at 7:30 p.m., Jorgensen and Markham (1946) found a relative humidity above 70 per cent and below 39 per cent unfavorable to the daily honeyflow, while the optimum was between 50 and 69 per cent. They also pointed out that the above figures were probably high because of the lateness of the hour at which they were taken. Littlefield (1941) reports that seasons of low humidity produced honey of higher quality, lighter color, heavier and thicker body, and better body than were produced during seasons of high humidity. Scullen (1940) stated that the relative humidity shows a highly significant negative correlation to the sugar concentration of fireweed nectar.

Mitchener (1927) found that the more sunshine per day, the greater the amount of nectar gathered by the bees. Hambleton (1925) found a correlation of +0.6214 between daily net gains and the daily hours of sunshine, and a correlation of +0.5525 between daily net gains and solar radiation. Kenoyer (1917a) and Jorgensen and Markham (1946) stated that clear days were favorable for honey production. Beutler (1934) stated that the darkening of a plant decreased the nectar flow from that plant. Kenoyer (1917b) stated that the sugar secretion by plants greatly diminished in darkness, but the water secretion may continue, depending on the species of plant. Tschudin (1921) stated that the honey yield increased as the elevation increased. He studied colonies both at sea level and at different elevations in the French Pyrenees.

He found that colonies located between 4,000 and 5,000 feet above sea level yielded almost three times as much honey as those located between sea level and 1,000 feet. Vansell (1940) stated that sunlight caused maximum nectar secretion of poinsettia blossoms. Lundie (1925) stated that light was the controlling factor regulating bee flights, and on heavily overcast days the bees remained within the hive due to the low intensity of light. Braun (1945) found no evidence of correlation between the hours of sunshine and the daily honeyflow.

Kenoyer (1917a) stated that a low barometric pressure was favorable for a good honeyflow. Kenoyer (1917b) stated that the fluctuations in yield appeared to be correlated with the barometric pressure and the daily temperature acting jointly. Jorgensen and Markham (1946) found a slight tendency for a normal or slightly above normal barometric pressure to be the most favorable for a heavy honeyflow.

Kenoyer (1917a) stated that south winds appeared to be slightly favorable for honey production, but he pointed out that this probably was due to the fact that they often brought clearer and warmer weather. He stated further that east winds were generally unfavorable, probably because they usually brought clouds and rain. He found no significant differences in the winds from the other six major compass directions.

Jorgensen and Markham (1946) reported a slight tendency towards a series of good and poor years, but they also did not have two bumper crops in succession in Michigan. Kenoyer (1917a) found a definite alternation of good and poor years in Iowa. He stated that a poor year is usually preceded and followed by a good year, while a good year is usually preceded and followed by a poor year.

Mitchener (1947) stated that the July gains for colonies in Manitoba have remained about the same from 1930 through 1946, while August yields have been much reduced since 1930. He stated further that this is because farmers grow less sweet clover than formerly was the case. The sweet clover weevil has been the partial cause for the reduction in sweet clover acreage. He also stated that the sweet clover that is grown is not managed as favorably for the beekeepers as formerly. Farmers formerly grew it for pasture after they had cut a hay crop. The sweet clover bloomed and it provided a good August honeyflow for the beekeeper. Now the farmers plow under the stubble as soon as the sweet clover hay crop is removed in an effort to preserve the soil moisture. Mitchener (1947) reported that dandelion bloom in late May and early June was an important stimulating honeyflow. He reported further that the main honeyflow was usually between June 21 and August 27.

COLONY WEIGHT AND WEATHER RECORDS

Daily records of the gains and losses in weight of colonies during the honeyflow have been taken at the Kansas Agricultural Experiment Station Apiary at Manhattan since 1918. The late Dr. J. H. Merrill supervised the taking of these records from 1918 to 1925, inclusive. Students working for Dr. R. L. Parker have taken the readings from 1926 until the present time. Information pertaining to the record making is given in Table 1.

Table 1. Summary of the number of colonies weighed, including the years with inclusive dates, and the name of the recorder.

Year	Period of records	Number of colonies weighed	Name of the recorder
1918	June 1 - Sept. 30	3	Frank Van Haltern
1919	May 31 - Sept. 30	6	C. S. Rude
1920	June 12 - Sept. 29	6	Ida Adee
1921	June 21 - Aug. 12	6	H. P. Gaston
1922	June 1 - Sept. 30	5	Noennig & H. A. Horn
1923	May 31 - Sept. 30	8	C. L. Farrar
1924	June 9 - Sept. 11	7	C. L. Farrar
1925	June 8 - Aug. 30	7	C. L. Farrar
1926	June 14 - Sept. 30	6	C. B. Keck
1927	Sept. 3 - Sept. 30	6	C. B. Keck
1928	June 26 - Sept. 29	5	Marshall, Carruth, & Meroney
1929	No records taken		
1930	June 9 - Sept. 30	7	Louis A. Kelly
1931	June 1 - Sept. 30	7	E. J. McNay
1932	May 31 - Sept. 30	6	E. J. McNay
1933	May 31 - Sept. 30	6	E. J. McNay
1934	May 31 - Sept. 30	6	E. J. McNay
1935	May 31 - Sept. 30	6	E. J. McNay
1936	June 3 - Sept. 30	6	Marion C. West
1937	June 1 - Sept. 28	6	Marion C. West
1938	July 2 - Aug. 18	5	Roy Fritz
1939	June 24 - Sept. 26	5	C. E. Hornbuckle
1940	June 3 - Sept. 30	5	Robert C. Yapp
1941	June 1 - Aug. 24	5	Robert C. Yapp
1942	June 3 - Sept. 30	5	Victor C. Thompson
1943	May 31 - Sept. 30	5	Victor C. Thompson
1944	June 11 - July 20	5	Roy O. Wilbur
1945	June 2 - Sept. 30	5	Louis Combs
1946	June 9 - Sept. 18	5	Robert C. Yapp
1947	June 12 - Sept. 22	5	Robert C. Yapp
1948	June 5 - Sept. 24	4	Robert C. Yapp

Strong colonies were placed on scales at the beginning of the recording period and left on the scales for the duration of the honeyflow. Each scale colony was weighed daily at dusk. Unfortunately, no readings were made for the 1929 season, while the records for a few other years were not as complete as desired. However, the records available provide suitable material for study, and this paper explores only a few of the many possibilities of conclusions they offer.

Table 2 is a sample of the original data taken at the Kansas Agricultural Experimental Station Apiary.

Table 2. A sample of colony weights recorded at the Kansas Agricultural Experiment Station Apiary at Manhattan.

Date: 1944, June	Colony numbers				
	1	2	4	11	13
			Pounds		
11	124.50	115.50	117.50	141.00	113.00
12	125.75	117.00	118.50	142.00	114.00
13	126.50	118.00	119.00	142.50	115.50
14	127.00	117.00	118.75	144.00	115.00
15	129.50	118.00	120.00	146.50	117.00
16	131.00	119.00	121.50	148.50	119.00
17	131.75	119.75	122.00	152.25	119.00
18	135.00	120.25	123.50	157.25	120.00
19	135.00	120.00	123.00	157.50	120.00
20	136.00	120.00	123.00	157.00	120.00
21	138.00	119.75	125.75	158.00	122.00
22	139.00	120.00	127.50	159.00	122.50
23	142.00	121.00	131.00	163.25	125.00

Recorded by Roy O. Wilbur

The daily gains or losses per colony for all years was calculated from data similar to that shown in Table 2. Table 3 shows how the daily gains or losses in pounds per colony and the average daily gains or losses per colony was calculated in this study. The data used in this study are the figures calculated from the average daily gains or losses per colony.

Table 3. A sample of the daily gains and losses in pounds of each colony and the average daily gains or losses per colony as calculated from the colony weights shown in Table 2.

Date 1944 June	Colony numbers 1	2	4	11	13	Average daily gain or loss per colony
11	124.50*	115.50*	117.50*	141.00*	113.00*	
12	1.25	1.50	1.00	1.00	1.00	1.15
13	0.75	1.00	0.50	0.50	1.50	0.85
14	0.50	-1.00	-0.25	1.50	-0.50	0.05
15	2.50	1.00	1.25	2.50	2.00	1.85
16	1.50	1.00	1.50	2.00	2.00	1.60
17	0.75	0.75	0.50	3.75	0.00	1.15
18	3.25	0.50	1.50	5.00	1.00	2.25
19	0.00	-0.25	-0.50	0.25	0.00	-0.10
20	1.00	0.00	0.00	-0.50	0.00	0.10
21	2.00	-0.25	2.75	1.00	2.00	1.50
22	1.00	0.25	1.75	1.00	0.50	0.90
23	3.00	1.00	3.50	4.25	2.50	2.85

* Initial total weights of the scale colonies.

The weather information was obtained from "Climatological Data, Kansas section" Volumes 32-62 by Flora (1918-1948) published by the Weather Bureau of the United States Department of Commerce, and two Kansas publications, "Kansas Weather and Climate" by Cardwell and Flora (1942) and "Climate of Kansas" by Flora (1948). Other weather information was obtained from the Department of Physics, Kansas State College, Manhattan, Kansas.

PRESENTATION AND DISCUSSION OF DATA

The Honeyflow

The colonies at Manhattan usually increased colony populations on yellow sweet clover, then stored most of the surplus honey from white sweet clover. This was the main honeyflow, and it usually occurred in June and early July. Naturally, the time of this honeyflow varied in starting and ending dates, length of time, and intensity depending upon many factors. There was usually a second, smaller honeyflow occurring in August. Alfalfa and smartweed were responsible for this late honeycrop. Many other plants and trees contribute to the spring "build up", and taken together they make an important contribution towards securing a surplus of honey.

Table 4 shows the amount of honey stored at different semimonthly intervals. The poorest honeyflow years were 1936 and 1934, six colonies storing an average of 3.80 pounds of nectar in 1936, and six colonies storing an average of 10.27 pounds of nectar in 1934. During 1943 and 1946 five colonies stored an average of over 210 pounds of nectar per colony, while 1940 was the third best nectar producing year recorded with five colonies storing an average of 198.00 pounds. In 1935 six colonies stored an average of 11.50 pounds of nectar the last 15 days of September; this was the only year recorded in which the scale colonies stored more nectar than they consumed during the last half of September. Five colonies stored an average of 116.62 pounds of nectar during

Table 4. Average amount of nectar in pounds, stored by semi-monthly intervals at Kansas Agricultural Experiment Station Apiary, Manhattan, Kansas from 1918 to 1948 inclusive.

Year	Inclusive days recorded	No. of colonies	Pounds of nectar stored per colony							Season's total June 1 - Sept. 15
			June 1-15	June 16-30	July 1-15	July 16-31	Aug. 1-15	Aug. 16-31	Sept. 1-15	
1918	June 1 -Sept.15	3	8.75	1.13	33.62	6.06	2.48	-1.07	-1.65	49.32
1919	May 31-Sept.15	6	0.45	-0.44	1.54	8.10	-1.82	23.06	21.45	52.34
1920	June 12-Sept.15	6	-0.67	7.40	27.86	23.90	24.30	8.88	-5.20	86.47
1921	June 21-Aug. 12	6	----	4.31	33.28	9.97	-3.90	----	----	43.66
1922	June 1-Sept.15	5	13.75	18.37	17.88	17.61	4.88	-5.76	-8.99	57.74
1923	May 31-Sept.15	8	-1.49	16.33	13.19	-2.66	-3.31	-3.88	7.23	25.41
1924	June 9-Sept.11	7	3.12	9.41	49.01	9.41	31.27	15.83	-6.05	112.00
1925	June 8-Aug. 30	7	10.13	63.19	49.65	3.50	41.92	-0.57	----	167.82
1926	June 14-Sept.15	6	-0.70	12.02	29.92	9.35	22.03	1.84	-4.33	70.13
1927	Sept. 3-Sept.15	6	----	----	----	----	----	----	-6.29	Incomplete
1928	June 26-Sept.15	5	----	11.33	55.68	18.00	1.12	-6.00	-5.80	74.33
1929	No records taken									
1930	June 9-Sept.15	7	15.74	81.81	43.49	3.58	1.82	4.39	5.16	155.99
1931	June 1-Sept.15	7	-5.20	54.79	14.82	-1.87	2.48	10.80	-5.84	69.98
1932	May 31-Sept.15	6	30.04	76.25	59.69	0.50	11.47	3.86	-3.09	178.72
1933	May 31-Sept.15	6	-5.53	38.20	49.28	32.81	21.53	-7.61	-5.88	122.80
1934	May 31-Sept.15	6	-3.22	23.61	0.27	-5.51	-4.86	-1.00	1.00	10.27
1935	May 31-Sept.30	6	13.16	30.55	36.54	-2.55	11.60	12.15	15.70	128.55*
1936	June 3-Sept.15	6	14.74	-5.08	-2.94	-4.55	4.50	-2.58	-0.29	3.80
1937	June 1-Sept.15	6	-4.12	-6.39	-3.26	33.41	22.08	16.17	-4.60	53.27
1938	July 2-Aug. 18	5	----	----	15.68	9.63	47.65	2.00	----	74.96
1939	June 24-Sept.15	5	----	8.96	35.91	-7.10	24.60	42.79	-1.66	103.50
1940	June 3-Sept.15	5	34.58	116.62	22.45	-10.40	2.15	22.25	10.35	198.00
1941	June 1-Aug. 24	5	30.62	82.02	20.80	-2.80	-9.50	-0.80	----	120.34
1942	June 3-Sept.15	5	27.80	40.66	36.70	-5.95	3.90	32.90	-3.01	133.00
1943	May 31-Sept.15	5	22.06	110.95	78.05	-3.55	-7.15	11.95	2.45	214.76
1944	June 11-July 20	5	3.90	12.10	17.09	9.05	----	----	----	42.14
1945	June 2-Sept.15	5	2.32	63.27	55.00	40.15	12.10	23.30	-3.70	192.44
1946	June 9-Sept.15	5	13.27	82.05	76.90	21.49	9.40	16.70	-9.38	210.43
1947	June 12-Sept.15	5	3.33	33.50	60.64	-13.35	4.62	61.70	2.10	152.54
1948	June 5-Sept.15	4	64.50	18.86	57.00	29.90	32.75	-3.87	-8.62	190.52

* A gain of 11.50 pounds per colony stored between September 16 and 30 is included in the total for 1935.

the last half of June in 1940, while during the same period in 1943, five colonies stored an average of 110.95 pounds of nectar. These were by far the best semi-monthly periods studied.

The 10 best nectar storing years listed in descending order were 1943, 1946, 1940, 1945, 1948, 1932, 1925, 1930, 1947, and 1942. The 10 poorest nectar storing years listed in descending order were 1936, 1934, 1923, 1944, 1918, 1919, 1937, 1922, 1931, and 1926. Because of the incompleteness of the record for 1921, it was not considered as one of the 10 poorest years. The year 1944 was considered one of the 10 poorest years because the record was complete for the main honeyflow, and it was in the lower 10 years for this period.

The average amount of nectar stored in semi-monthly periods during the honeyflow is given in Table 5, the table also shows what percentage of the honeyflow is gathered at different semi-monthly periods. Over 60 per cent of the honeycrop was stored in the month between June 16 and July 15. Three-fourths of the surplus was obtained during June and the first half of July, while 19 per cent of the crop was obtained in August. Sometimes a surplus was stored in September, and in 1935 the nectarflow continued until October 1, with six colonies making a gain of 11.50 pounds during the last 15 days of September. From the standpoint of nectar stored by the bees, the last half of July was the poorest semi-monthly period of the season consisting of the months of June, July, and August. The average amount of nectar stored from June 1 until September 15 was 116.25 pounds.

Table 5. The average amount of nectar in pounds and the average percentage of the yearly honeyflow stored semi-monthly from June 1 until September 15 from 1918 to 1948 inclusive.

Date	Pounds of nectar stored	Percentage of nectar stored
June 1-15	14.79	12.7
June 16-30	38.18	32.8
July 1-15	34.49	29.6
July 16-31	7.64	6.6
Aug. 1-15	11.15	9.6
Aug. 16-31	10.79	9.3
Sept. 1-15	-0.79	-0.7
Total	116.25	99.9

There was no indication of an alternation of good and poor years over the entire three decade period, although during some periods there was an alternating effect, while at other times the good years appeared to run in series, and the bad years appeared to run in series. There was apparently no relationship between the honeycrop of a good year and a good honeycrop the preceding or following year. There also was no relationship between the honeycrop of a poor year and a good honeycrop the preceding or following year.

Long-term Weather Influences on the Honeyflow

Relation of Precipitation to Honey Production. Water is essential for the life of a plant, with most higher plants depending directly or indirectly upon precipitation for enough water to maintain their life processes. The amount of rainfall and the season at which it falls does much to determine the kind and vigor of the plant life of an area. The vegetation of a region is the basis of the honeyflow, and areas where grasses and cereal crops are dominant usually have few colonies of bees or beekeepers.

The average annual precipitation at Manhattan, Kansas is 32 inches, with over 23 inches falling in the six months between April and September. These six months are the growing season for most of the important honey plants of this area.

An attempt was made to find a relationship between the rainfall for a given time and the 10 best and the 10 poorest honeyflow years. This analysis is shown in Table 6. The average

Table 6. Average precipitation in inches for the 10 best honeyflow years, which were 1943, 1946, 1940, 1945, 1948, 1932, 1925, 1930, 1947, and 1942, and the 10 poorest honeyflow years, which were 1936, 1934, 1923, 1944, 1918, 1919, 1937, 1922, 1931, and 1926.

Period considered	Average precipitation for 10 best years	Average precipitation for 10 poorest years
Calendar year	33.19	30.40
Preceding calendar year	35.61	30.51
Preceding Sept. - May	20.18	19.36
Preceding Sept. - Nov.	8.38	8.15
Preceding Dec. - Feb.	2.90	2.34
Preceding Mar. - May	8.89	8.87
Preceding April	3.66	3.17
Preceding May	3.65	3.60
June	7.47	2.99
July	2.80	3.52
August	3.72	3.56

precipitation was slightly higher for the 10 best years studied than for the 10 poorest years in every period in Table 6 except

July. There is evidence that abundant rainfall was favorable to the honeyflow, plentiful rainfall in June being particularly favorable to a good honeycrop.

The June rainfall for the good years averaged two and one-half times as much as for the poor years. To find if these data were significant, a statistical test known as the test of significance was used.

The formula for t is $\bar{x}\sqrt{\frac{n(n-1}{Sx^2}}$

n is number of units in each series.

$\bar{x}$ is the difference between the mean of the two series.

Sx^2 is the sum of the squares of each deviation from the mean for the series.

P is the probability of the value of t occurring by chance if there was no relationship between the two factors being tested.

Tables 7, 8, and 9 show how the values for $\bar{x}$, n, and Sx^2 were obtained when June rainfall was tested for relationship to the 10 best honeyflow years.

Table 7. Summary of statistics of rainfall for June in relation to the 10 best and the 10 poorest honeyflow years.

Years	Number of years	Degrees of freedom	Mean June rainfall	Sum of squares
Best	10	9	7.47	105.59
Poorest	10	9	2.99	26.41

Degrees of freedom = 18 $\bar{x}$ = 4.88 Sx^2 = 132.00

Table 8. Calculation of the sum of squares, Sx^2, for the 10 best years for June rainfall in relation to a good honeycrop.

Year	June rainfall	Deviation from mean June rainfall for 10 best years	Square of deviation
1925	6.57	-0.90	0.81
1930	6.39	-1.08	1.16
1932	4.88	-2.59	6.71
1940	4.06	-3.41	11.63
1942	11.48	4.01	16.08
1943	12.28	4.81	23.14
1945	7.93	0.46	0.21
1946	2.17	-5.30	28.09
1947	7.26	-0.21	0.04
1948	11.68	4.21	17.72
Total		0.00	105.59

Table 9. Calculation of the sum of squares, Sx^2, for the 10 poorest years for June rainfall in relation to a good honeycrop.

Year	June rainfall	Deviation from mean June rainfall for 10 poorest years	Square of deviation
1918	1.56	-1.43	2.04
1919	4.66	1.67	2.79
1922	3.52	0.53	0.28
1923	6.64	3.65	13.32
1926	1.74	-1.25	1.56
1931	2.80	-0.19	0.03
1934	1.89	-1.10	1.21
1936	0.75	-2.24	5.02
1937	3.39	0.40	0.16
1944	2.92	-0.07	0.00
Total		-0.03	26.41

Substituting the values in Table 7 in the formula for t, t would equal $4.48\sqrt{\frac{10(10-1)}{132.00}} = 4.48 \text{ times } \frac{9.5}{11.5} = 3.70$.

The value of t is 3.70 with 18 degrees of freedom. When the degrees of freedom are constant, the higher the value of t, the more significant is the relationship between the two factors being considered. Snedecor (1946, p. 65) gives the probability of a larger value of t than 2.878 with 18 degrees of freedom as less than one per cent. Since the value of t for June rainfall in relation to a good honeycrop was 3.70 with 18 degrees of freedom, there was less than one chance in 100 that abundant June rainfall was not favorable for a good honeycrop, or P was less than 1 percent.

June was the only period in Table 6 in which the rainfall was significantly related to either a good honeycrop or a poor honeycrop. None of the other differences was significant, but the fact that the best years averaged more rain in every preceding period studied suggests that perhaps abundant rainfall in the preceding months helps make possible a good honeycrop.

<u>Relation of Temperature to Honey Production</u>. Many apiculturists and beekeepers believe that temperature is the most important single ecological factor affecting the behavior of insects. It is known that bees are extremely sensitive to temperature changes, and they maintain temperatures between 93 and 95 degrees F. in the brood area at all times when the brood is being reared. Bees are cold-blooded animals, and therefore they cannot control their body heat, but they exercise temperature control

through group muscular activity.

The mean temperatures for different periods for the 10 best and the 10 poorest periods are listed in Table 10. A warm April appears to have been particularly favorable to the honeyflow, the 10 good years having Aprils with an average of 4.1 degrees F. higher mean temperature than the corresponding month in the 10 poor years. Cooler Mays and Junes than normal appear to have been favorable for a good honeycrop. May averaged 3.6 degrees F. cooler for the good honeyflow years than for the poor honeyflow years, while June averaged 3.1 degrees F. cooler during the best years than during the poorest years.

Table 10. Mean temperatures for different periods in relation to the 10 best years, which were 1943, 1946, 1940, 1945, 1948, 1932, 1925, 1930, 1947, and 1942, and the 10 poorest honeyflow years, which were 1936, 1934, 1923, 1944, 1918, 1919, 1937, 1922, 1931, and 1926.

Period considered	Average temperature for 10 best years in degrees F.	Average temperature for 10 poorest years in degrees F.
Calendar year	55.3	56.1
Preceding calendar year	55.9	56.1
Preceding Sept. - May	48.5	48.0
Preceding Sept. - Nov.	58.6	57.3
Preceding Dec. - Feb.	32.0	32.2
Preceding Mar. - May	54.8	54.4
Preceding January	26.4	29.7
Preceding February	38.6	33.5
Preceding March	43.8	43.0
Preceding April	57.8	53.7
Preceding May	62.9	66.5
June	73.9	77.0
July	80.1	81.7
August	79.5	81.2

April, May, and June were the only months of the periods analyzed to show any significant differences. A warm April in relation to a good honeycrop gave the t value of 2.93 with 18 degrees of freedom. Again P would be less than 1 per cent. A value of 2.39 was obtained for t in a test of the relationship of low June temperatures and a good honeyflow, giving a value for P of less than 5 per cent.

There were no long range temperature relationships which greatly affected the honeyflow. A warm April, and a cool May and June were significantly related to a good honeycrop. Otherwise, there were no significant relationships found between temperature and a good honeycrop.

Relation of Sunshine to Honey Production. The amount of nectar secreted by plants is influenced by the amount of sunshine received, and the intensity of the sun. Different species of plants react differently to the same quantity of sunshine, an optimum amount for one species may be too much for a second species, while it may not be a sufficient amount for a third species to maintain itself. Apparently there is also an optimum amount of sunshine for the bees. They are often cross on cloudy days, although this may be because of lower temperatures or a decrease in the honeyflow, and may not be directly related to the lack of sunshine. The number of bee flights is usually greatly reduced on cloudy and cooler days.

The results of an analysis of the relationship of the number of clear, partly cloudy, and cloudy days during May, June, July, and August to the 10 best and 10 poorest years of the honeyflow are shown in Table 11. In each of the four months studies, the number of cloudy days was greater during the good years than the poor years. In the four-month-period from May through August, there were over twice as many cloudy days during the 10 best years than the 10 poorest years.

Table 11. The average number of clear, partly cloudy, and cloudy days in May, June, July, and August to the 10 best honeyflow years, which were 1943, 1946, 1940, 1945, 1948, 1932, 1925, 1930, 1947, and 1942, and the 10 poorest honeyflow years, which were 1936, 1934, 1923, 1944, 1918, 1919, 1937, 1922, 1931, and 1926.

Period	Ten best years			Ten poorest years		
	Clear days	Partly cloudy days	Cloudy days	Clear days	Partly cloudy days	Cloudy days
May	12.6	8.9	9.5	15.0	11.0	5.0
June	12.9	10.0	7.1	17.3	9.8	2.9
July	17.7	8.8	4.5	21.0	9.2	0.8
August	16.3	9.2	5.5	17.4	10.6	3.0
May-Aug.	59.5	36.9	26.6	70.7	40.6	11.7

Cloudy days usually bring lower temperatures and higher relative humidities. The effect of these factors on the major honey plants of this area would greatly affect the honeyflow. Lower temperatures and higher relative humidities would slow up the transpiration rate of plants and help prevent them from drying out. This would help keep the plants in optimum growing condition for a longer period of time, and they would probably secrete nectar more profusely and for a greater length of time. Also, too much sunshine is frequently unfavorable for plants, and often they grow more vigorously if some of the sunshine is eliminated. It was probably a combination of several factors affecting plants and bee behavior resulting from cloudy weather which accounted for the favorable effect on the honeyflow.

A study of multiple factors acting jointly on the honeyflow and bee activity is now being made under the supervision of Dr. H. C. Fryer. This study may throw new light on the influence of weather factors affecting the honeyflow.

Influences of the Range of Daily Temperatures on the Honeyflow

Nectar secretion in plants varies greatly with changes in temperature. Such changes naturally would have a great effect on the amount of nectar collected. The optimum temperature for maximum nectar secretion varies with the species of plant, the soil conditions, and many other environmental factors.

In Table 12 only the daily gains of the days in June, July, and August from 1918 through 1948 were added together to give the amount of nectar stored at different temperatures. The most nectar was stored on days when the maximum temperature was between 90 and 94 degrees F. Ten per cent of the surplus nectar was produced on days when the maximum temperature was 100 degrees or above. Cool days had a bad effect on the honeyflow, only 3.3 per cent of the honeycrop was produced on days which had a maximum temperature below 80 degrees F.

Table 12. Total pounds of nectar stored by the average colony at different maximum daily temperatures during the three major honey-storing months, June, July, and August from 1918 through 1948.

Temperature degrees F.	Pounds of nectar stored: June	July	August	June-August	Per cent stored of June-August total
69 and under	0.58	0	0.20	0.78	0.0
70-74	10.62	5.35	4.25	20.22	0.6
75-79	58.19	11.89	22.38	92.46	2.7
80-84	224.95	65.75	56.39	347.09	10.2
85-89	391.52	349.90	169.36	910.78	26.7
90-94	447.40	451.22	177.77	1076.39	31.5
95-99	171.44	295.93	147.87	615.24	18.0
100-104	71.28	117.07	83.89	272.24	8.0
105-109	28.29	12.65	34.00	74.94	2.2
110 and over	2.00	0.04	4.70	6.74	0.2

All days between June 1 and the last of August were used in Table 12 in calculating the average amount of nectar stored per day at a given temperature. In June and July the best nectar storing days were when the maximum daily temperatures were between 90 and 94 degrees F., while in August a maximum temperature between 85 and 89 degrees F. yielded the most nectar per day. Extremely high maximum temperatures, 110 degrees F. or over, and extremely low maximum temperatures, 74 degrees F. and under, had a depressing effect on the daily honeyflow.

Table 13. Average number of pounds of nectar stored per day at different daily maximum temperatures, and the number of days studied, from June through August, 1918 to 1948 inclusive.

Temperature degrees F.	Average pounds stored				Number of days studied			
	June	July	Aug.	June Aug.	June	July	Aug.	June-Aug.
69 and under	-0.65	....*	....*	-0.65	19	2	2	23
70-74	-0.11	0.51	0.00	-0.01	25	5	9	39
75-79	0.55	0.33	0.25	0.43	64	14	37	115
80-84	1.80	0.77	0.43	1.10	106	56	82	244
85-89	2.29	1.88	0.93	1.71	162	174	157	493
90-94	3.45	1.97	0.86	1.94	128	218	181	527
95-99	2.18	1.60	0.75	1.39	76	174	155	405
100-104	1.35	0.66	0.64	0.77	48	129	102	279
105-109	0.61	-0.25	0.59	0.22	25	55	42	122
110 and over	....*	-0.35	-0.02	-0.13	1	22	25	48

* Less than five days available for analysis.

Figures 1 and 2 show Table 13 in graph form. Only periods in which there were five or more days available for study were graphed. Figure 1 shows the pounds of nectar stored per day at different maximum daily temperatures for the period from June 1 through the last of August. The maximum amount of nectar was stored when the maximum daily temperatures were between 90 and 94 degrees. The more degrees the maximum daily temperatures were, either above or below the 90 to 94 degrees F. mark, the less nectar was collected per day.

In Fig. 2 the amount of nectar stored per day is shown by monthly periods. The maximum daily temperatures most favorable for nectar storing were between 90 and 94 degrees in June and July, and between 85 and 89 degrees in August. Maximum temperatures

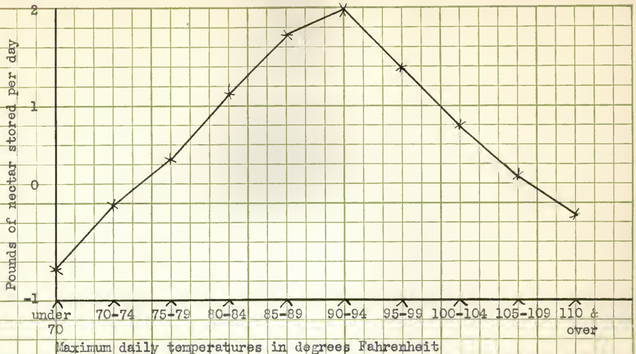

Fig. 1. Average number of pounds of nectar stored per day at different daily temperatures, June to August inclusive, and 1918 to 1948 inclusive.

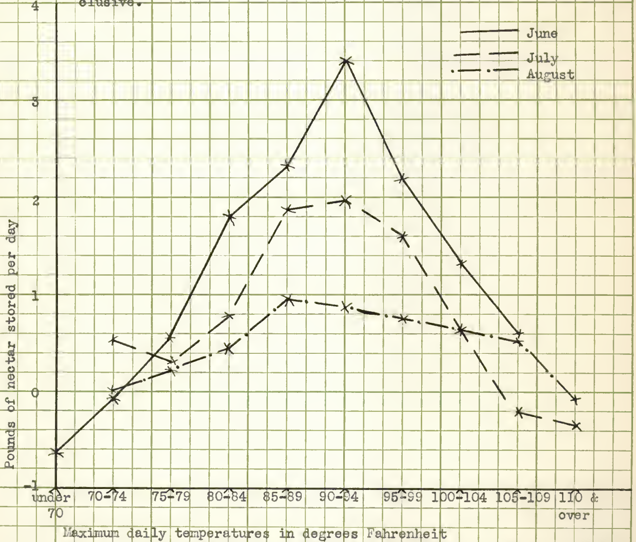

Fig. 2. Average number of pounds of nectar stored per day at different daily temperatures, by months, from June to August inclusive, and 1918 to 1948 inclusive.

either above or below 90 to 94 degrees F. during June and July tended to reduce the daily honeyflow, and the farther the maximum temperature ranged from 90 to 94 degrees F., the greater the drop in the amount of nectar gathered per day. The farther the maximum daily August temperatures ranged from the 85 to 89 degrees F., the greater the drop in daily honey production.

An intensive study of the relationship of differences in the daily maximum and minimum temperatures to the daily honeyflow was made. The differences were studied in five-degree groups under maximum temperatures which had also been sub-divided into five degree periods. Table 14 is a consolidation of these groups. The greater the range of daily June temperatures the better the honeyflow, until the range passed 30 degrees of temperature, beyond which point the daily honeyflow was reduced by increasing the spread between the daily maximum and the daily minimum temperatures. The best spread for a good honeyflow on a July day was between 21 and 25 degrees of temperature, while the daily honeyflow decreased as the daily range of temperatures becomes larger or smaller than this figure. The best temperature range for a good August honeyflow has been from 31 to 35 degrees of temperature.

Apparently the extremes were not favorable for a good daily honeyflow. When the daily range between maximum and minimum temperatures was under 10 degrees, very little nectar was stored, and when the daily range was over 40 degrees of temperature, the honeyflow was very weak.

Table 14. Daily average gains or losses in relation to the range of daily temperatures for June, July, and August, 1918 to 1948 inclusive.

Range of daily temperatures in degrees F.	Average number of pounds of nectar stored per day			
	June	July	August	June-August
6-10	-1.10	-0.72	-0.14	-0.60
11-15	0.44	0.29	0.37	0.39
16-20	1.80	1.54	0.74	1.36
21-25	2.21	1.73	0.77	1.55
26-30	2.57	1.33	0.68	1.39
31-35	2.37	1.21	0.85	1.37
36-40	1.82	0.68	0.48	0.88
41-45	-0.18	0.17	0.42	0.20
46 and over	----*	----*	----*	-0.09

* Less than five days available for analysis.

The effect of differences in the range of the maximum minus minimum daily temperatures at different maximum temperatures can be seen in Figs. 3 through 10. When the maximim temperature was between 70 and 89 degrees F., a greater range in daily temperatures appeared to favor a larger daily honeyflow (Fig. 3). However, when the maximum temperature was 90 degrees F. or over, there appeared to be little correlation between daily ranges in temperatures and a good daily honeyflow (Fig. 4). A wide spread in daily temperatures in June appeared to favor a good nectar storing day, until the maximum daily temperature reached 90 degrees F., after which there was apparently little relationship between the daily honeyflow and the range in daily temperatures (Figs. 5 and 6). A similar situation appears to exist for July, a wide range of daily temperatures appearing favorable until the daily maximum temperatures reached 90 degrees F., after which there was little relationship between daily gains and a wide range in daily temperatures (Figs. 7 and 8). In August there was apparently no relationship between daily range in temperatures and the amount of nectar stored in a given day (Figs. 9 and 10).

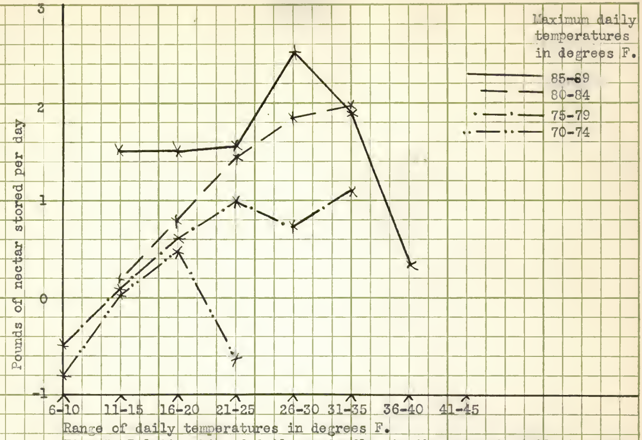

Fig. 3. Relationship of daily nectarflow to the range in daily temperatures and maximum daily temperatures between 70 and 89 degrees F., June through August, and 1918 to 1948 inclusive.

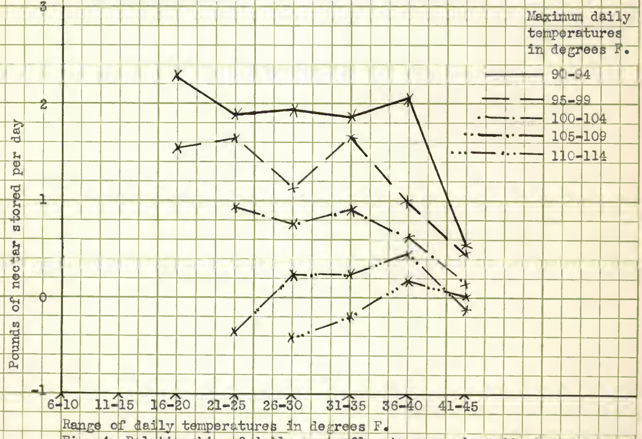

Fig. 4. Relationship of daily nectarflow to range in daily temperatures and maximum daily temperatures between 90 and 114 degrees F., June through August, and 1918 to 1948 inclusive.

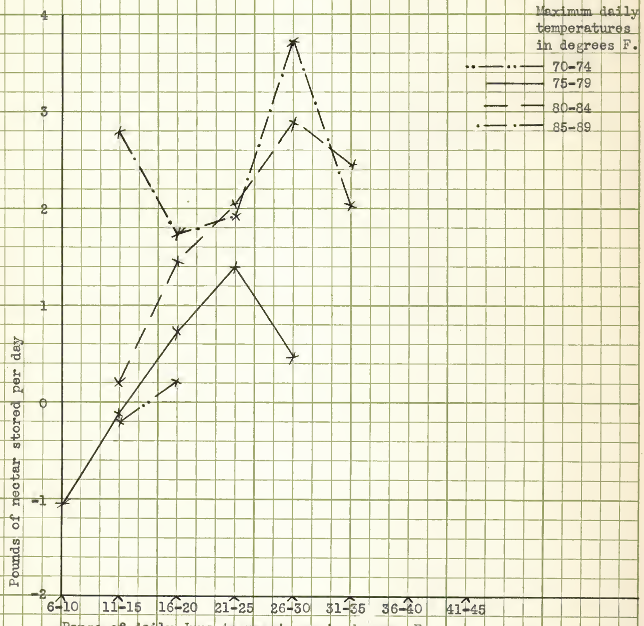

Fig. 5. Relationship of daily nectarflow to range in daily temperatures and maximum daily temperatures between 70 and 89 degrees F. for June, 1918 to 1948 inclusive.

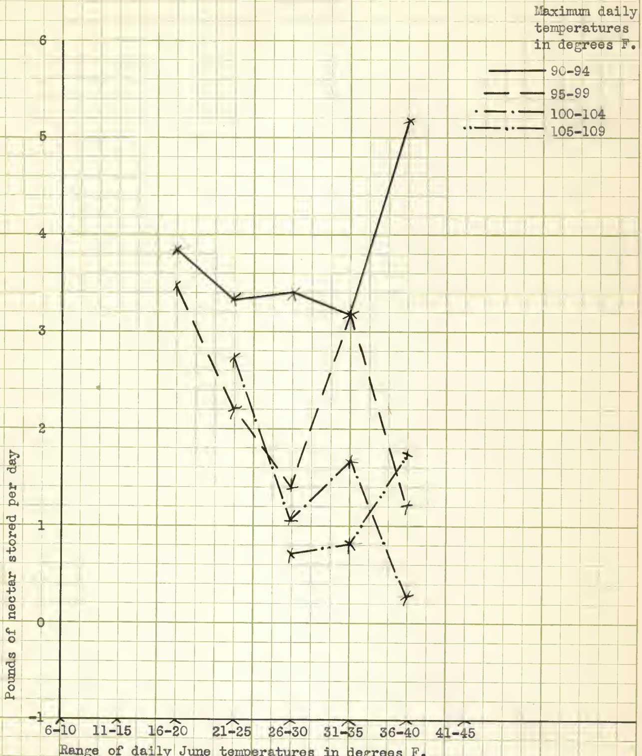

Fig. 6. Relationship of daily nectarflow to range in daily temperatures and maximum daily temperatures between 90 and 109 degrees F. for June, 1918 to 1948 inclusive.

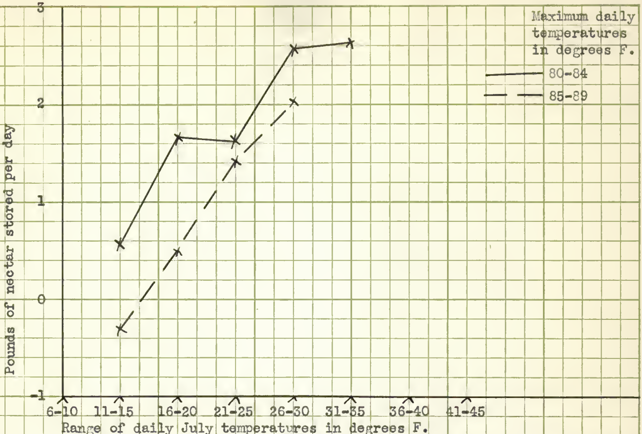

Fig. 7. Relationship of daily nectarflow to range in daily temperatures and maximum daily temperatures between 80 and 89 degrees F. for July, 1918 to 1948 inclusive.

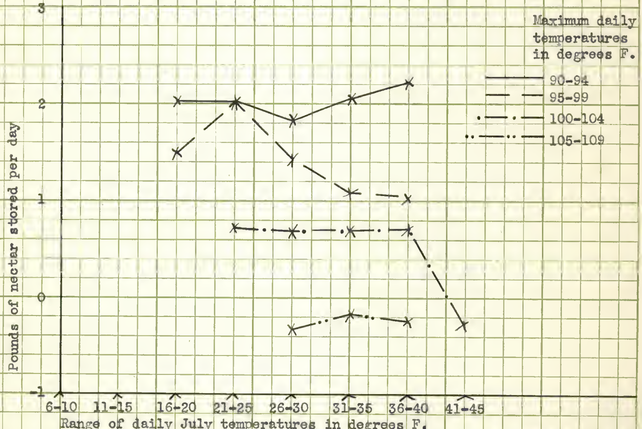

Fig. 8. Relationship of daily nectarflow to the range in daily temperatures and maximum daily temperatures between 90 and 109 degrees F., 1918 to 1948 inclusive.

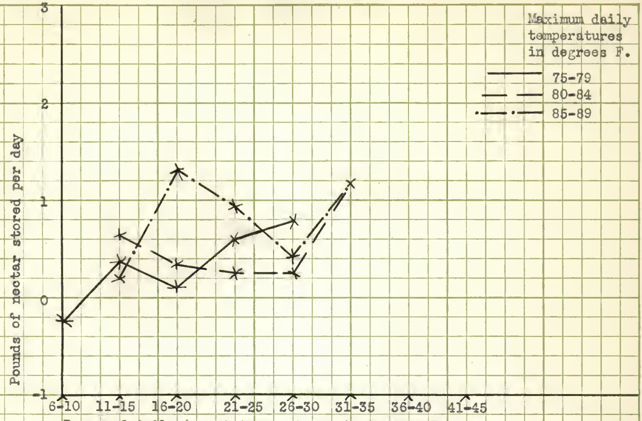

Fig. 9. Relationship of daily nectarflow to range in daily temperatures and maximum daily temperatures between 75 and 89 degrees F. for August, 1918 to 1948 inclusive.

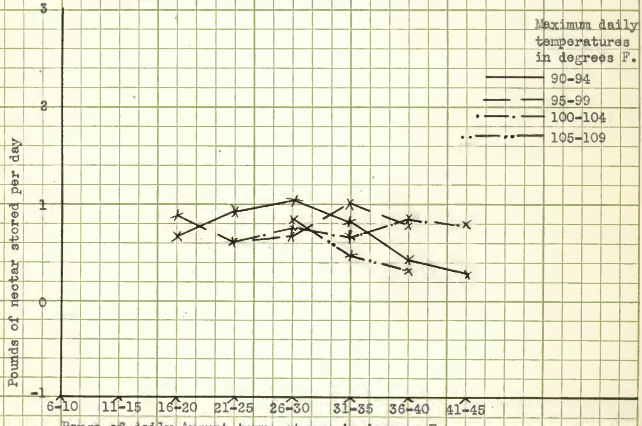

Fig. 10. Relationship of daily nectarflow to range in daily temperatures and maximum daily temperatures between 90 and 109 degrees F. for August, 1918 to 1948 inclusive.

SUMMARY

Daily records of the gains and losses of scale colonies have been kept at the Kansas Agricultural Experiment Station Apiary at Manhattan, Kansas since 1918. From three to eight colonies were placed on scales each year on or about June 1 at the beginning of the honeyflow, and they usually were removed from the scales 10 to 15 days after the last gain was recorded during the latter part of September. The average daily changes in weights in these colonies were used in all the work done in this study.

The amount of nectar stored varied greatly from year to year, six colonies stored an average of 3.80 pounds per colony in 1936 and the same number of colonies stored an average of 10.27 pounds of nectar per colony in 1934. These were the two poorest years recorded. In 1943 five colonies stored an average of 214.76 pounds per colony, while in 1946 five colonies stored an average of 210.43 pounds per colony, making them the two best nectar storing years recorded.

Six colonies stored an average of 11.50 pounds of nectar during the last half of September in 1935. This was the only year in which a gain was made during the last half of September. The best semi-monthly nectar storing periods were during the last half of June in 1940, when five colonies stored an average of 116.62 pounds of nectar per colony, and in the same period in 1943 when five colonies stored an average of 110.95 pounds of nectar per colony.

Over 60 per cent of the honeycrop was stored between June 16 and July 15. Three-fourths of the surplus was obtained during June and the first half of July, while 19 per cent of the honeycrop was obtained in August. The average amount of nectar stored from June 1 until September 15 was 116.25 pounds per colony.

There was no evidence of an alternation of good and poor honeyflow years. During some periods there was an alternation of good and poor years, while at other times the good and poor years appeared to run in series.

June rainfall for the 10 best years averaged 7.47 inches, while it averaged only 2.99 inches for the 10 poorest years. Abundant June rainfall was significantly related to the 10 best honeyflow years. The rainfall for the preceding year, the calendar year, the preceding fall, the preceding winter, and the preceding spring were not significantly related to the 10 best or the 10 poorest honeyflow years.

A warm April and a cool May and June were significantly related to the 10 best honeyflow years. The mean temperature for the preceding year, the calendar year, the preceding fall, and the preceding winter were not significantly related to the 10 best or the 10 poorest honeyflow years.

The number of cloudy days in the four months from May to August, inclusive, averaged 26.6 days during the 10 best years, and only 11.7 days during the 10 poorest years.

Over 58 per cent of the nectar was stored on days when the maximum daily temperatures were between 85 and 94 degrees F. Ten per cent of the nectar was stored on days when the maximum temperature was 100 degrees F. or over, but only 3.3 per cent of the honeycrop was stored when the maximum daily temperature was under 80 degrees F.

The best maximum daily temperatures for a good daily nectar flow during June and July were between 90 and 94 degrees F., but in August a maximum daily temperature between 85 and 89 degrees F. was best for a good daily honeyflow.

The best daily range of temperatures for a good June honeyflow is between 26 and 30 degrees of temperature. The July honeyflow was strongest when the daily range in temperatures was between 21 and 25 degrees of temperature, while a daily range of 31 to 35 degrees of temperature was most favorable for a good daily honeyflow in August. Extremely larger or extremely smaller ranges in daily temperatures were not favorable for a good daily honeyflow.

A wide spread in daily temperatures in June appeared favorable to a good daily honeyflow, until the maximum daily temperature reached 90 degrees F., after which point there apparently was little relationship between the daily honeyflow and the range in daily temperatures. A similar situation appeared to exist for July, a wide range in daily temperatures appearing favorable until the daily maximum temperature reached 90 degrees F., after which there was little relationship between daily gains and a wide range in daily temperatures. In August there apparently was no relationship between daily range in temperatures at different maximum temperatures and the amount of nectar stored in a given day.

ACKNOWLEDGMENT

Thanks are due Dr. R. L. Parker for his invaluable advice in this study. It was his suggestion that led to the undertaking of this work. The late Dr. J. H. Merrill and Dr. R. L. Parker, as well as the many students who assisted in the taking of these records, made this study possible by their faithful taking of the daily weights of the scale colonies for the past three decades.

Dr. Holly C. Fryer gave valuable advice on the statistical methods to be applied to the data. Dr. Alvin B. Cardwell and the Department of Physics were helpful in making available weather records, thereby making it possible to obtain more information than would be otherwise possible.

Dr. Roger C. Smith, Head of the Department of Entomology, made many valuable suggestions during the writing of this thesis.

LITERATURE CITED

Braun, Ed.
The honeyflow and weather data. Glean. in Bee Cult. 73: 198-201. 1945.

Beutler, Ruth.
Biologisch-chemische Untersuchungen am Nektar von Immenblumen Zeitschr. Wissensch. Bio. Abt. C. Zeitschr. Vergleich Physiol. 12(1): 72-176. 23 figs. 1930. (Biol. Abstr. 9: 2167. 1934)

Cardwell, A. B., and S. D. Flora.
Kansas weather and climate. Kans. Agr. Expt. Sta. Bul. 302: 53-54. 1942.

Dalton, Jes.
Reaction of a scale colony to a rainy day in the midst of a heavy honeyflow. Amer. Bee Jour. 71: 423. 1931.

Demuth, George S.
Comb honey. U.S.D.A. Farmers' Bul. 503: 18-19. 1912.

__________ Temperature and nectar secretion. Glean. in Bee Cult. 51: 582. 1923.

Flora, S. D.
Climatological data, Kansas section. U. S. Dept. Commerce, Vol. 32-62. 1918-1948.

__________ Climate of Kansas. Kans. St. Bd. Agr. Rep. 67(285): 320 p. 1948.

Hambleton, James I.
The effect of weather upon the change in weight of a colony of bees during the honeyflow. U.S.D.A. Bul. 1339. 52 p. 1925.

Jorgensen, Carl, and Floyd Markham.
Weather factors influencing honey production. Mich. Agr. Expt. Sta. Spec. Bul. 340. 22 p. 1946.

Kenoyer, Leslie A.
Environmental influences on nectar secretion. Ia. Agr. Expt. Sta. Res. Bul. 37: 219-232. 1916.

__________ The weather and honey production. Ia. Agr. Expt. Sta. Bul. 169: 15-26. March, 1917a.

Kenoyer, Leslie A.
Environmental influences on nectar secretion. Bot. Gaz. 63: 249-265. April, 1917b.

Littlefield, Roy.
Relative humidity as a factor in honey production. Amer. Bee Jour. 81: 359-360, 408, 422. 1941.

Lovell, John H.
The weather and honey production. Amer. Bee Jour. 64: 280-283. 1924.

Lundie, A. E.
The flight activities of the honeybees. U.S.D.A. Bul. 1328. 37 p. 1925.

Mitchener, A. V.
Influence of temperature on the honeyflow. Amer. Bee Jour. 67: 120-121. 1927.

________ Manitoba honey flows 1924-1946. Jour. Econ. Ent. 40: 854-860. 1947.

Munro, J. A.
A study of the factors influencing the yield of honey during the main nectar flow. Jour. Econ. Ent. 22: 518-521. 1929.

Oertel, Everett.
Effect of temperature and relative humidity on sugar concentration of nectar. Jour. Econ. Ent. 39: 513-515. 1946.

Park, O. W.
The influence of humidity upon sugar concentration in the nectar of various plants. Jour. Econ. Ent. 22: 534-544. 1929.

Scullen, H. A.
Relative humidity and nectar concentration in fireweed. Jour. Econ. Ent. 33: 870-871. 1940.

Snedecor, George W.
Statistical methods. Fourth edition. Ames, Iowa: Iowa State College Press, 1946.

Tschudin, Ernest.
Nectar secretion affected by altitude. Glean. in Bee Cult. 49: 100. 1921.

Vansell, Geo. H.
Nectar secretion in poinsettia blossoms. Jour. Econ. Ent. 33: 409-410. 1940.

Vansell, Geo. H.
Alfalfa nectar and the honeybee. Jour. Econ. Ent. 34: 21-23. 1941.