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THE FLIGHT RANGE OF THE HONEYBEE[1]

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INTRODUCTION AND REVIEW OF LITERATURE

The economic value of the honeybee depends, for the most part, upon its ability to pollinate flowers and to produce a surplus of honey and beeswax. In selecting a proper location for an apiary, therefore, one must consider not only the flora, climate, topography, and the nature of the soil, but also the distances bees must fly in quest of food. With respect to the last factor, a review of the available literature has failed to reveal much pertinent information.

As early as 1844 Huish (*5, p. 419–429*)[3] reviewed the writings of Huber and others and gave an account of his own experiences in contrast to the opinions then current concerning the distances bees fly in search of nectar and pollen. He stated that some of his bees flew 3 miles to hills richly covered with heath and that he knew of an instance in which bees flew at least 4 miles over water to gather nectar on an island. Other investigators of that period were of varying opinions on this question, giving distances of from 1 to 4 miles, according to Huish. It is apparent from his writings, however, that the distances given were merely estimated and thus subject to considerable error.

Waite (*11*) in 1898 advised that it was necessary to have sufficient bees at least within 2 or 3 miles of an orchard to effect the proper pollination of pomaceous fruits. Hutson (*7*) found under New Jersey conditions that for best results colonies should be scattered within an orchard at the rate of approximately one colony to the acre.

Miller (*8, p. 148*), in Illinois, considered that if the distance was greater than 2 miles the quantity of honey would be reduced. Hutchinson (*6*), in Michigan, thought that bees would range for 2.5 miles in all directions from a given apiary, while Dadant (*3, p. 65*) wrote that as a general rule bees (near Hamilton, Ill.) made their harvest of honey

[1] Received for publication Feb. 4, 1933; issued September 1933. This paper was presented, in part, as a dissertation in partial fulfillment of the requirements for the degree of doctor of philosophy, received in June 1931 from the Ohio State University. The experimental work upon which this paper is based was done while the writer was associate apiculturist, Division of Bee Culture, Bureau of Entomology, U.S. Department of Agriculture, and located at the intermountain bee culture field laboratory at Laramie, Wyo. The experiments were conducted in Wyoming and Colorado under a cooperative agreement with the University of Wyoming.

[2] The writer is indebted particularly to H. Rauchfuss, A. D. Hardy, E. O. Rauchfuss, F. G. Rauchfuss, and G. H. Sechrist for their cooperation, and to Aven Nelson, professor of botany and president emeritus at the University of Wyoming, for the identification of the plants collected in the areas in which the experiments were conducted.

[3] Reference is made by number (italic) to Literature Cited, p. 285.

within a radius of 2 km (1.25 miles). Dadant also stated that he believed bees would fly much farther in following a small valley, or when working on flowers along a road, than in passing above a forest or a hill. Buttel-Reepen (*2, p. 162*) found that bees would orient themselves within a circle of 3 to 4 km (1.86 to 2.48 miles), and where nectar was available at a greater distance from the apiary, with no other source intervening, they would fly 5, 6, and even 7 km (3.11 to 4.35 miles), and under exceptional conditions 12 km (7.46 miles).

One of the most concrete reports reviewed by the writer on the flight range of the honeybee was that of Gowland (*9, p. 54*). Gowland found that the seed yield of fields of sweetclover located beside an apiary was much heavier than that of any other field except one three eighths of a mile away. A field 4.5 miles from the apiary had a very light yield of seed. In the same report he states: "* * * the bees seemed to concentrate their efforts on certain fields rather than to take the fields in order according to distance from their hive." Gowland thought that this might be one reason why the yield of seed did not decrease directly with an increase in distance.

A considerable difference is also found in laws intended to regulate the location of apiaries. A New Zealand law (*1*), for example, requires that beekeepers keep their colonies at least 5 miles from the fruit-drying centers, while a Utah law *(4)* makes it unlawful for migratory beekeepers to locate their apiaries within 2 miles of an established apiary. The same Utah law also requires that all hospital yards (for the treatment of diseased colonies) be located at least 2 miles from other apiaries.

It is reasonable to suppose that the differences in opinion as to the effective flight range of the honeybees may be due to a certain extent to the effect of the locations on the distances the bees had to fly, or they may have been due to a lack of careful observation or to a combination of the two factors. The experiences of such able beekeepers as Miller, Dadant, Hutchinson, and many others have led them to believe that the flight range of the honeybee varies somewhat according to the physical factors of different locations.

The present paper reports the results of experiments conducted in Wyoming and Colorado on the flight range of honeybees and their distribution within a nectar-producing area. The experiments were conducted during the summers of 1927, 1928, 1929, and 1930 and may be divided into three phases. The first observations were made on the flight of bees from colonies located on a prairie during a dearth of nectar when an artificial source of food was provided. In the second series observations were made on colonies located on a stretch of badlands lying between two irrigated districts supporting good growths of alfalfa and sweetclover, and in the third, experiments were conducted with apiaries located within sweetclover territory.

FLIGHT OF HONEYBEES TO AN ARTIFICIAL SOURCE OF FOOD

The first attempt to determine the flight range of the honeybee was made on a wide stretch of prairie west of Laramie, Wyo. The location seemed an excellent one in which to determine the distances bees would fly to an artificial source of food when no important natural source was available.

The Big Hollow, essentially a wind-blown formation about 9 miles long by 3 miles wide and so called because its floor lies between 100 and 150 feet below the level of the surrounding country, contains several fresh-water and alkaline lakes and several ridges (fig. 1). The floor of the formation, which is fairly level to rolling with the exception of the ridges, is covered with grasses, small clumps of cacti, and other vegetation kept short by a lack of moisture and is devoted largely to the grazing of range animals. At the time of the experiment there were no trees or even sagebrush to break the landscape. Only five widely scattered, abandoned homesteads were located in the hollow, and but a small portion of the entire area was under fence.

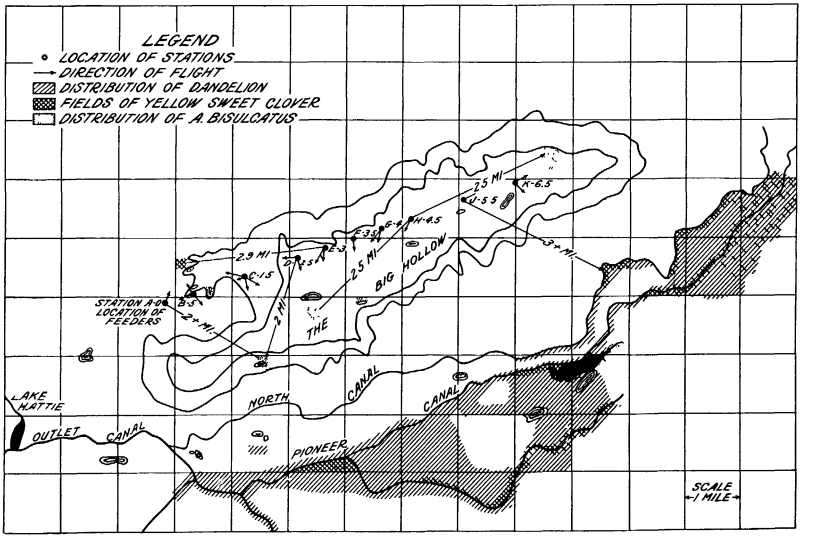

FIGURE 1.—The Big Hollow, west of Laramie, Wyo., where the first attempts were made to determine the flight range of the honeybee.

Numerous wild flowers were present during the period of the experiment, but they were of little importance except for furnishing pollen. Certain members of the genus *Astragalus* which covered small areas in the vicinity of the lakes were visited by the bees for pollen and possibly a little nectar. Near the west end of The Big Hollow 3 acres had been planted to yellow sweetclover several years before, but at the time of the experiment the sweetclover covered only about three fourths of an acre. This field came into bloom near the close of the observations. Other than this one field of sweetclover, the nearest nectar-producing plants, dandelion and sweetclover, were at least 3 miles from the center of The Big Hollow.

EQUIPMENT AND METHODS

On June 1, 1927, twenty 1-story colonies of Italian bees of approximately equal strength were moved into The Big Hollow and distributed at 10 stations which extended in a straight line for 6.5 miles (fig. 1). In the western portion of The Big Hollow the first station, A-0, was located. From this point the line of the stations extended

northeasterly away from the direction of the prevailing winds with the colonies faced toward station A-0. A small shack and a few outbuildings at station A-0 were used as temporary headquarters.

Two feeders (fig. 2) were placed in the open at station A-0 and were kept filled with a sirup made of 20 pounds of granulated sugar and 5 pounds of sweetclover honey dissolved in 75 pounds of water. This solution was colored light red with a vegetable dye found to be non-injurious and nonrepellent to the honeybee.

In order to determine from what stations the bees came or to what stations they returned after their visits to the feeders, the majority of bees in one colony at each station and most of the bees that came to the feeders were marked with distinctive colors. The various colors were applied to the bees at the stations in the form of a fine spray as they crawled up the sides of a box into which they had been shaken. The coloring materials consisted of suspensions of paint pigments in shellac and ethyl alcohol, 1 part shellac and 1 part pigment, by weight, to 4 parts of alcohol. Thus the bees in one colony at station B-0.5 [4] were marked with burnt umber, those at station C-1.5 with Indian red, etc. Most of the bees that visited the feeders were marked individually with vermilion.

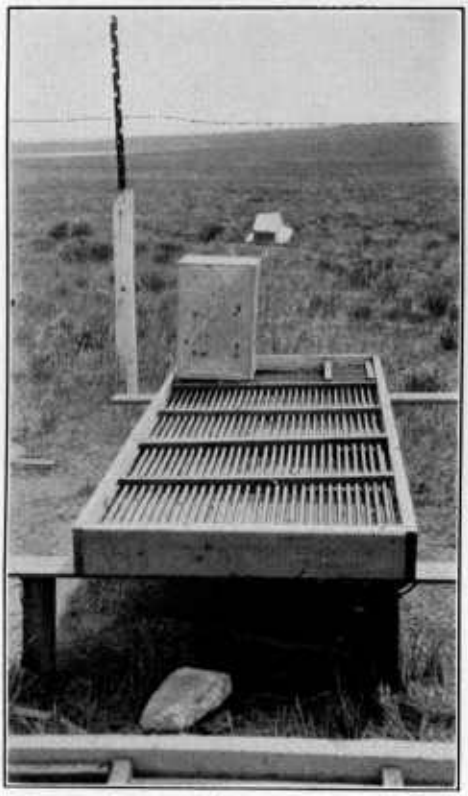

FIGURE 2.—Type of feeder for honeybees used in The Big Hollow.

Although spraying the bees with the alcohol-shellac mixture apparently had no lasting harmful effect upon them, it did not prove a success, as but small quantities of the pigments adhered to their bodies. Some of the bees were well marked, but they were too few to be of much use in determining the flight from any one station or in finding the marked bees in the field. Several hundred bees in each colony were later marked individually, and the pigments adhered to them for many days.

In order to determine whether the bees had procured an appreciable quantity of sirup or any other food, whenever the weather conditions permitted each colony was weighed before flight started in the morning and again after flight had stopped for the day.

Records were kept of the general climatic conditions during the period of the experiment.

[4] The numbers after the station letters refer to the distance in miles each station was located from the feeders.

At each station pollen was collected from returning bees at various intervals for later determination.

In many instances when bees were discovered on plants in the field, they were marked in order that they could be identified later at their hives. When bees so marked in the field were found in their hives, the distance between the hive and the area in which they were marked was recorded.

The hives at each station were searched, generally near the close of each day, for bees marked in the field or at the feeders to determine if any sirup was being carried.

RESULTS

The bees at station A-0 flew to the feeders within a few hours after they had been set out and obtained a significant quantity of sirup during the period of the experiment. The bees at station B-0.5 were at the feeders on the second day after the sirup had been made available. The colonies at that station, however, did not accumulate enough sirup during the entire time of the experiment to show an increase in weight, although the loss was less than that of colonies at the other stations. The bees of only one colony at station C-1.5 found the feeders and then only after some of the field bees had been carried to the feeders where they were fed, marked, and released. The day after this was done, other bees from the same colony also found the feeders. The colonies at station C-1.5 lost weight during the period of the experiment, but the average loss in weight was less than that recorded at the more distant stations (table 1). No bees located beyond the 1.5-mile station were ever seen at the feeders.

TABLE 1.—*The average net gain or loss in weight, by stations, of the colonies in The Big Hollow, June 5 to July 10, 1927, when sugar sirup was used as a source of food*

Station	Gain (+) or loss (−) in weight	Station	Gain (+) or loss (−) in weight
	Kilograms		*Kilograms*
A-0	+2.33	F-3.5	[a]
B-0.5	−1.48	G-4	−5.27
C-1.5	−3.40	H-4.5	−5.48
D-2.5	−5.49	J-5.5	−4.04
E-3	−5.48	K-6.5	−3.51

[a] Queenless.

Several attempts were made to induce the bees to fly farther than 1.5 miles by baiting them with sirup-filled tins which were moved by short stages in the direction of the feeders. No bees could be made to follow these tins for more than 0.7 mile. This may have been due to the general absence of landmarks, as in one instance it was noted that a marked bee, bearing pollen, made a mistake of one-half mile in the location of its own hive. An automobile used in making the rounds to the stations had stopped at the station from which the marked bee came before moving on to the next station, one-half mile distant. The bee evidently included the automobile among the landmarks when it left for the field and in returning flew to the station at which the automobile had stopped.

Bees were traced for at least 3 miles from several stations and were found carrying certain pollens that were available only outside of The Big Hollow.

Near the close of the experiment the field of yellow sweetclover near station A-0 came into bloom, as did also the sweetclover growing to the east and south of the line of colonies. The bees deserted the feeders for these fields and carried sweetclover pollen to all stations but F-3.5. The two colonies at this station were queenless during the greater part of the experiment. Several hundred bees were marked as they worked in the sweetclover near station A-0. Bees thus marked were found at stations A-0, B-0.5, C-1.5, D-2.5, and E-3, but at none of the other stations. The bees at the stations beyond E-3, with the exception of F-3.5, had to fly out of The Big Hollow, a distance of at least 3 miles, for the sweetclover pollen they obtained.

TABLE 2.—*Weather conditions at station A-0 in The Big Hollow in 1927*

Date	Wind				Temperature			Character of sky
	Average velocity	Prevailing direction	Maximum velocity	Direction of maximum velocity	Highest	Lowest	Average	
	Miles per hour		*Miles per hour*		*° F.*	*° F.*	*° F.*	
June 4	8.8	NE.	16.0	N.	80	61	71.1	Partly cloudy.
June 5	11.7	NW.	17.5	W.	57	47	58.9	Do.
June 6	3.0	NW.	13.0	NE.	67	47	59.9	Do.
June 7	10.1	NW.	21.5	N.	79	48	68.5	Do.
June 8	17.6	SW.	30.5	SW.	81	53	72.7	Do.
June 9	16.5	W.	28.5	NW.	72	58	67.7	Clear.
June 10	13.6	SW.	22.5	S.	82	48	69.9	Partly cloudy.
June 11 [a]	9.5	SW.	23.5	SE.	74	50	63.7	Do.
June 12	13.0	SE.	19.0	E.	52	43	48.2	Do.
June 13	11.0	SE.	13.8	SE.	59	41	50.2	Do.
June 14	5.4	SE.	14.0	NE.	68	42	55.1	Cloudy.
June 15 [b]	16.0	N.	28.0	N.	53	48	49.4	Do.
June 16	11.4	NW.	24.5	NW.	68	37	59.0	Partly cloudy.
June 17	17.9	W.	34.5	W.	74	49	61.2	Do.
June 18	10.7	S.	23.5	NW.	77	55	66.3	Do.
June 19	8.0	SW.	35.5	W.	76	50	61.3	Do.
June 20	20.2	N.	26.5	N.	65	54	61.5	Clear.
June 21	16.7	N.	26.0	N.	62	49	55.5	Partly cloudy.
June 22	2.7	(?)	16.0	S.	70	40	61.8	Clear.
June 23	22.7	W.	32.5	SW.	84	66	78.9	Do.
June 24	21.7	W.	32.5	W.	87	69	80.5	Do.
June 25	18.1	SE.	30.5	SE.	84	55	72.2	Do.
June 26	19.3	SW.	30.5	SW.	86	68	79.8	Partly cloudy.
June 27	15.3	SW.	24.5	SW.	79	63	70.2	Do.
June 28	6.6	SE.	13.0	NW.	66	58	60.5	Do.
June 29	13.6	SW.	41.0	SW.	74	55	63.6	Do.
June 30	18.2	NW.	28.5	W.	65	49	58.5	Do.
July 1	10.6	SW.	23.5	W.	75	47	65.9	Clear.
July 2	11.7	SW.	28.0	SW.	80	54	72.3	Do.
July 3	15.8	SW.	27.0	SW.	80	60	72.4	Partly cloudy.
July 4	16.8	SW.	37.0	W.	81	59	67.3	Do.

[a] Last observations taken at 5:30 pm.
[b] No observations made between 8 a.m. and 12:30 p.m.

The combs in the colonies at stations G-4, H-4.5, J-5.5, and K-6.5 showed that the bees obtained nectar and pollen apparently from the dandelion which grew abundantly at distances of 3 and 4 miles from these stations. The colonies at stations J-5.5 and K-6.5 obtained enough nectar from dandelion and sweetclover to minimize losses in weight.

The weather conditions (table 2) that prevailed during the period of the experiment were not altogether favorable to bee flight. The

comparatively low temperatures, together with the large number of cloudy and windy days, tended to retard the activities of the bees. It was evident, however, that the bees flew farther for pollen and nectar than they did for sirup. Whether or not bees will fly more than 1.5 miles to an artificial source of food in locations containing more landmarks was not ascertained.

FLIGHT OF HONEYBEES TO A NATURAL SOURCE OF FOOD

LOCATION

The second phase of these experiments was conducted in northwestern Wyoming in the summers of 1927, 1928, and 1929, on two irrigated areas separated by at least 17 miles of badlands (fig. 3).

The general contour of the country between the two irrigated areas is comparatively level for the first 5 miles from its northern border and then becomes rolling to rough until the bench land at the south is reached. Drainage is toward the Shoshone River on the north, and the slope of the land is such that parts of the green fields and the trees bordering the river are visible from the badlands at a distance of several miles. In fact, both irrigated areas can be seen from many points along the old winding stagecoach road that connects the two.

The creeks in the badlands (fig. 3) were dry during the summer months except for short periods after rains and were marked by wide flood plains overgrown with denser vegetation than that which grew on the higher land.

The summer vegetation in this area consisted, for the most part, of small clumps of cacti (*Opuntia fragilis*), stunted sagebrush (*Artemisia tridentata*), some greasewood (*Sarcobatus* sp.), an admixture of the saltbushes (*Atriplex*), rabbitbrush (*Chrysothamnus*), which grew along the stream beds, and a scattering of various grasses, sedges, and dead stalks of spring-flowering plants. The small composite *Machaeranthera tanacetifolia* grew in abundance on the badlands in 1927 and 1928, and its color added a dash of blue to the otherwise gray aspect (fig. 4). Only a few gnarled and twisted cottonwoods were found along the banks of Coon and Whistle Creeks. The only plants from which bees could secure nectar were confined to the irrigated areas. Numerous prairie-dog mounds and large ant hills, the latter in the center of cleared spaces several feet in diameter, and a double row of telephone poles which crossed the badlands between the irrigated areas may have served as landmarks for the bees in their flights over this semidesert land. The irrigated areas, on the other hand, were known to be good beekeeping territory, and a number of commercial apiaries were located there.

EQUIPMENT AND METHODS

As it was evident that the badlands could provide no appreciable source of nectar for bees during the period of the experiments, the general plan of procedure called for the placing of colonies on the badlands at various distances from the irrigated area bordering the Shoshone River. The bees would thus be compelled to fly to the irrigated areas for nectar, and it was thought that records of the gains or losses in weight of the colonies would indicate the effect of distance upon their activities in the matter of honey production. The

fact that they actually flew to the irrigated areas was checked further by the identification of the pollens they carried.

The colonies used in the experiments in 1927 and 1928 were taken from apiaries located near Powell, Wyo., and as far as possible were of uniform strength in adult bees and brood. Each colony used in 1929 consisted of 4 pounds of bees and 4 frames of brood taken from

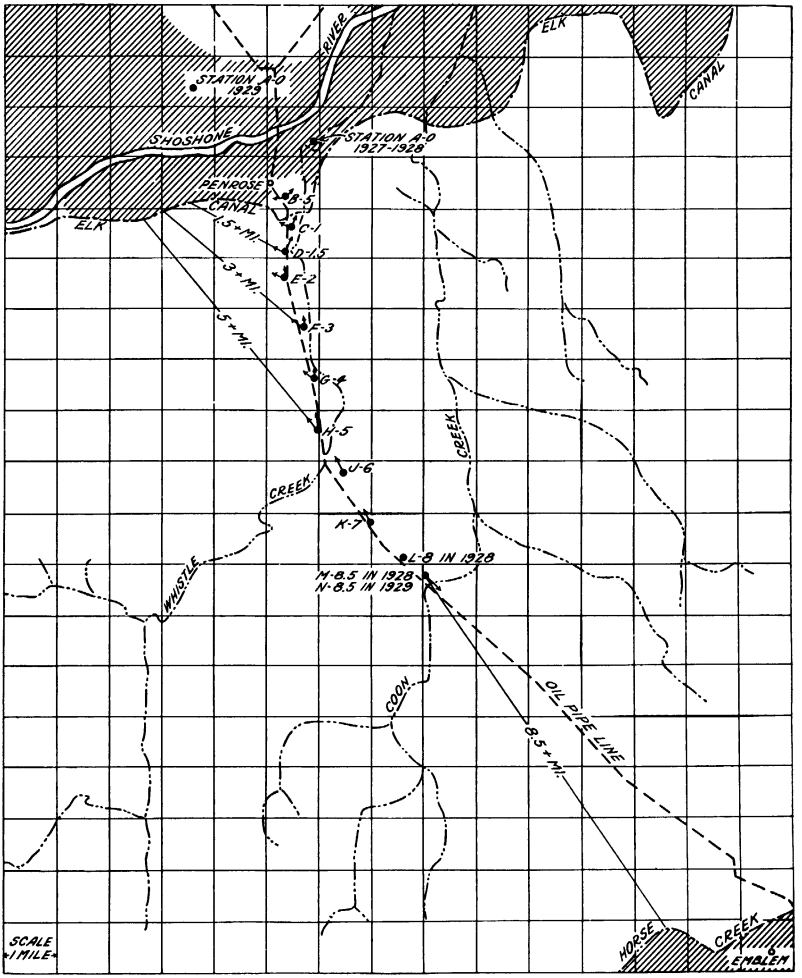

FIGURE 3.—A diagram of the district east of Powell, Wyo., in which the honeybee-flight experiments were conducted in 1927, 1928, and 1929. The shaded areas represent the irrigated areas in which fields of alfalfa and sweetclover were located. The badlands lie between them. Colonies were located at the stations numbered and the directions of flight are indicated by arrows.

overwintered colonies. An attempt was made to secure the 4 pounds of bees and a queen from 1 colony for each colony formed. In several instances, however, bees had to be obtained from two or more colonies in order to secure the 4 pounds. In such cases laying queens were introduced into the newly formed colonies. Equal numbers of Caucasian and Italian colonies were included in each of the 3 years. The

colonies used in 1927 and 1928 were somewhat stronger than those used in 1929.

The colonies were placed in practically the same locations each year, although certain changes in the number of stations were made during 1929, as will be described later.

The stations, each consisting of several colonies, were located with the aid of a map issued by the United States Reclamation Service (*10*). The distances between the stations and certain points in the irrigated area bordering the Shoshone River were checked either by an automobile odometer or by surveying instruments. Consequently the distances given in this report represent the minimum distances the bees had to fly on quiet days. On windy days these distances would be increased somewhat, especially for the bees located at the stations beyond 5 miles, as on such days the bees flew close to the ground and often had to deviate from a straight line.

In 1927 three colonies were placed at each of the first 10 stations (fig. 3). The first group of colonies, at station A-0, was 0.5 mile

FIGURE 4.—A typical spot on the badlands, showing the characteristic vegetation.

within the irrigated area. The other 9 stations were on the badlands in a line extending practically at right angles to the irrigated area along the Shoshone River, the last station (K-7) being 7 miles from a source of nectar.

In 1928, 5 colonies were placed at each of the first 2 stations, 4 at station C-1, and 3 at each of the other 7 stations. After the first week one colony was moved from station B-0.5 and another from C-1 to the positions indicated as L-8 and M-8.5, respectively.

Forty-two colonies were used in 1929. Station A-0 was placed farther within the irrigated area in what was considered an even better location than it occupied in 1927 and 1928; it contained 4 colonies, 2 Caucasian and 2 Italian. The next 9 stations, which occupied the same positions as during the 2 previous years, also contained 2 Italian and 2 Caucasian colonies each. The eleventh station, N-8.5, contained 1 Caucasian and 1 Italian colony. After observations had been made for 13 days, the colonies at stations K-7, J-6, H-5, and G-4

were moved to stations closer to the source of nectar. A second shift of colonies was made after another 13-day period, at which time the colonies at stations C-1, E-2, and F-3 were concentrated at stations A-0, B-0.5, and D-1.5.

None of the colonies were manipulated more than was necessary to provide supers or stores as needed, and all were examined alike on the same days. Colonies more than 4 miles from the irrigated areas were supplied with honey. There was no swarming during the 3 years, although some colonies became queenless. The records of the queenless colonies have not been included in the data.

All hives at the first 10 stations were weighed each evening after the bees had stopped flying, unless weather and road conditions prohibited. When the observations were omitted on any day during the period of the experiment, the figure recorded for the following day represented the net loss or gain for 2 days, so that this figure will be larger than when only 1 day's loss or gain is included. Generally, there was less than an hour's difference between the time the first and the last colony was weighed. In 1928 it was impracticable to weigh the colonies at stations J-6 and K-7 as often as the other colonies because of rains which made Whistle Creek impassable. The colonies at these two stations and those at stations L-8 and M-8.5 were moved across this creek before the termination of the experiment.

OBSERVATIONS AS TO DISTANCE OF FLIGHT

The bees began to carry in pollen within a few hours after they were placed at the stations. The fact that the pollen carried was sweet clover indicated that the bees flew from 0.5 mile to 7 miles in 1927 and at least 8.5 miles in 1928 and 1929. As these figures represent the minimum distances from the nectar source, additional flight was necessary for the bees to obtain a load of pollen or nectar. In all probability the bees at the 8.5-mile station flew at least 18 or 20 miles on each round trip.

All bees within 7 miles of the irrigated area bordering the Shoshone River flew north, while those at the 8.5-mile station flew to the irrigated area in the opposite direction. The nectar sources at the south were approximately 0.1 mile closer to the station 8.5 miles out than were the nectar sources at the north. No bees were observed to return to the 8.5-mile station from the north.

The direction of flight of the bees from any one station was generally over a narrow angle and in one particular direction, although some bees flew in other directions as well.

EFFECT OF DISTANCE OF FLIGHT UPON THE GAIN OR LOSS IN WEIGHT OF COLONIES

Experiments in 1927

All the normal colonies at stations within 4 miles of the irrigated area increased in weight. Colonies beyond the 4-mile point lost weight. The average gain in weight of the colonies at station A-0, located within the source of nectar, was somewhat less than that of the colonies 0.5 mile out on the badlands. From the 0.5-mile station the average gain in weight per station decreased gradually with an increase in distance, until a loss was recorded at the station 5 miles out, and the average loss became greater at stations J-6 and K-7, respectively (table 3 and fig. 5).

TABLE 3.—*Daily average net gain (+) or loss (−) in weight of the colonies at the different stations, August 1927*

Station	Colonies	Average gain or loss per colony, in kilograms, on August—																Total of daily average net gains or losses in weight	Average daily net gain or loss in weight for 18-day period
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	[a]16	17	18	
	Number																	*Kilograms*	*Kilogram*
A-0	2	−0.25	+0.29	+1.81	+1.34	+1.30	+0.11	+0.12	+1.50	+1.67	−0.37	+2.08	−0.08	+0.17	+0.21	+0.80	+0.77	+0.01	+11.48	+0.637
B-0.5	3	−.14	+.33	+2.40	+1.95	+1.81	+.30	+.17	+1.83	+1.87	−.06	+2.05	−.17	+.48	+.10	+.58	+.95	−.08	+14.37	+.798
C-1	3	−.14	+.16	+1.74	+1.68	+1.36	−.17	+.12	+1.18	+1.55	−.16	+2.05	−.72	+.30	+.06	+.52	+.89	+.15	+10.57	+.587
D-1.5	3	−.34	+.09	+2.00	+1.64	+1.62	+.14	−.12	+1.19	+1.30	−.15	+1.89	−.76	+.22	−.07	+.44	+.67	−.10	+9.66	+.537
E-2	3	−.02	−.14	+.87	+1.64	+1.42	−.17	−.24	+1.08	+1.36	−.24	+1.88	−.84	+.27	+.23	+.36	+.84	−.06	+8.24	+.458
F-3	3	−.10	−.20	−.01	+.168	+2.00	−.82	−.53	+1.24	+1.38	−.31	+1.77	−.92	+.05	+.19	+.30	+.70	−.15	+6.27	+.348
G-4	3	−.18	−.08	−.51	+.31	+1.88	−.54	−.62	+.79	+.91	−.31	+1.20	−.77	−.13	+.02	−.05	+.51	−.07	+2.36	+.131
H-5	3	−.15	−.20	−.48	−.43	+.71	−.47	−.49	+.24	+.52	−.32	+.78	−.74	−.12	−.06	−.18	+.18	−.18	−1.39	−.077
J-6	3	−.18	−.14	−.37	−.49	−.20	−.24	−.35	−.09	+.24	−.34	+.56	−.75	−.08	−.02	−.24	.0	−.14	−2.83	−.157
K-7	3	−.04	−.04	−.24	−.45	−.43	−.40	−.26	−.19	−.20	−.28	−.30	−.57	+.07	+.02	−.10	−.30	−.20	−3.91	−.217

[a] No records were obtained for Aug. 15, but those obtained on Aug. 16 include the net loss or gain for both Aug. 15 and 16.

Colonies at all stations lost weight on the first day after they had been placed in position. On the second day the colonies at the stations up to and including station D-1.5 gained weight. A gain was made at the 2-mile station on the third day. Stations F-3 and G-4 showed the first gain on the fourth day, and station H-5 made a gain on the fifth day. The colonies 6 miles away from the source of nectar made a small gain on the ninth day, but thereafter the total losses were greater than the gains. The colonies at the 7-mile station made a slight gain in weight on the thirteenth day, but as in the case of the colonies at stations H-5 and J-6 the average total losses were greater thereafter than the gains (table 3).

From the standpoint of honey production, 1927 was considered a poor year by the beekeepers operating in the territory where these experiments were conducted.

Experiments in 1928

Inasmuch as the colonies at the 5-, 6-, and 7-mile stations lost weight during 1927, each colony in 1928 was given a shallow super of honey as a reserve food chamber, but these had to be removed within a few days and replaced with supers of foundation in order to provide room for the nectar that the bees were bringing in. The food chambers were left on the colonies at stations L-8 and M-8.5.

The colonies at each of the first 10 stations made material gains. The average daily gain or loss in weight per colony was again less at the station within the nectar-producing area than at some of the stations out on the badlands. The effect of distance was less pronounced in 1928 than it was in 1927. In 1928 a distance of 3 to 5 miles showed little effect on the average daily gain or loss in weight, although the average gain was greater for the colonies at C-1, D-1.5, E-2, and F-3 than for those at the other stations. The average data for this period show that the colonies 0.5 to 2 miles away from the irrigated area made greater gains than the colonies within the area. Beyond the 3-mile point a gradual decrease in weight roughly proportional to the increase in distance was recorded. The average daily gain, however, of the colonies 7 miles from the source of nectar in 1928 closely approximated that of the colonies within the irrigated area in 1927 (fig. 3 and tables 3 and 4).

TABLE 4.—*Daily average net gain (+) or loss (−) in weight of the colonies at the different stations, July 1928*

Station	Colonies	Average gain or loss per colony, in kilograms, on July—															Total of daily average net gains or losses in weight	Average daily net gain or loss in weight for 23-day period
		3	5	8	10	12	14	15	17	19	20	21	22	23	24	25		
	Number																*Kilograms*	*Kilograms*
A-0	5	+0.30	+1.14	+0.87	+1.06	+2.39	+2.32	+0.82	+1.15	+3.49	+0.48	+1.80	+1.96	+1.63	+1.95	+1.33	+22.69	+0.987
B-0.5	4	+.38	+1.11	+.90	+.68	+2.53	+2.81	+.59	+1.25	+3.82	+.66	+2.05	+1.80	+1.69	+1.67	+1.06	+23.00	+1.000
C-1	3	−.07	+1.13	+1.16	+1.09	+2.89	+4.25	+1.38	+1.85	+4.89	+.94	+3.09	+2.40	+2.55	+3.05	+2.48	+33.08	+1.438
D-1.5	3	−.78	+.84	+1.02	+1.07	+2.50	+3.48	+1.08	+1.63	+3.17	+.81	+2.40	+2.27	+2.09	+2.11	+1.14	+24.83	+1.080
E-2	3	−.48	+.43	+.74	+.80	+3.07	+3.53	+1.16	+1.57	+3.16	+1.04	+2.78	+2.32	+2.19	+2.50	+1.23	+26.04	+1.132
F-3	3	0.00	+.45	+2.36	+1.40	+3.81	+3.15	+.93	+1.33	+2.80	+.77	+2.09	+1.61	+1.44	+1.90	+1.02	+25.06	+1.090
G-4	3	−.03	+.53	+1.02	+.94	+1.91	+1.88	+.69	+1.46	+1.13	+.63	+1.86	+1.42	+1.43	+1.87	+.77	+17.51	+.761
H-5	3	−.15	+.75	+1.31	+1.19	+2.89	+2.75	+1.19	+1.55	+1.16	+1.13	+2.15	+1.45	+1.87	+1.91	+1.06	+22.21	+.966
J-6 [a]	3	+.02	+1.01	-------	+.64	-------	-------	-------	+8.45	-------	-------	-------	-------	+3.83	-------	-------	+13.95	+.664
K-7 [a]	3	−.33	+.79	-------	+1.60	-------	-------	-------	+6.74	-------	-------	-------	-------	+3.47	-------	-------	+12.27	+.584

The colonies at stations J-6 and K-7 were weighed at irregular intervals, the last weights being taken on July 23. The average was therefore for a 21-day period.

The colonies at stations A-0 and B-0.5 made an average gain in weight the first day, while all the other colonies lost weight, with the exception of those at F-3, which showed no change, and at J-6, where there was a slight gain. The colonies were not weighed again until the third day, by which time all had increased in weight (table 4).

Beekeepers in the vicinity considered honey production to be above the average in 1928.

Experiments in 1929

First period

During the first part of the experiment in 1929 (July 3 to 15) the colonies were in practically the same positions as in 1927 and 1928, except that station A-0 was moved to what was thought to be a more favorable location within the irrigated area, and only one station, N-8.5, was situated beyond K-7.

The colonies on the badlands at stations B-0.5, C-1, D-1.5, and E-2 again made greater average gains in weight than the colonies at station A-0, which was within the irrigated area. Beyond the 2-mile point the adverse effect of distance was increasingly apparent, until losses were recorded at stations J-6 and K-7, as well as at N-8.5 (table 5).

Table 5.—*Daily average net gain (+) or loss (−) in weight of the colonies at the different stations during the first period, July 3 to 15, 1929*

Station	Colonies	Average gain or loss per colony, in kilograms, on July —									Total of daily average net gains or losses in weight	Average daily net gain or loss in weight for 13-day period
		3	4	6	9	10	11	12	14	15		
	Number										*Kilograms*	*Kilograms*
A-0	[a] 3	+0.85	+1.03	+2.39	+1.41	+1.34	+0.61	+1.86	+1.36	+0.64	+11.49	+0.884
B-0.5	4	+1.14	+1.24	+3.06	+1.73	+1.33	+.64	+1.75	+1.55	+.82	+13.26	+1.020
C-1	4	+1.38	+1.38	+2.86	+2.30	+.90	+.41	+1.54	+1.47	+.37	+12.61	+.970
D-1.5	4	+1.48	+1.55	+3.25	+1.83	+.94	+.21	+1.59	+1.32	+.21	+12.38	+.952
E-2	4	+1.53	+1.56	+3.50	+1.31	+.91	+.26	+1.63	+1.15	+.15	+12.00	+.923
F-3	3	+1.05	+1.17	+3.41	+.93	+.60	−.11	+1.34	+1.13	+.03	+9.55	+.735
G-4	4	+.18	+.43	+1.63	+.44	+.26	−.13	+.78	+.61	−.07	+4.13	+.318
H-5	3	−.13	+.03	+.84	+.08	+.10	−.24	+.45	+.52	−.18	+1.47	+.113
J-6	4	−.18	−.26	−.29	−.43	+.10	−.33	−.02	+.05	−.21	−1.57	−.121
K-7	4	−.03	−.39	−.43	−.26	−.14	−.17	−.27	−.16	−.12	−1.97	−.151
N-8.5	2										−1.75	−.134

[a] 2 of the 5 colonies originally located at station A-0 became queenless during this period and, being abnormal, their production was not recorded.

In this period the colonies were not weighed until the second day after they had been placed on location. By that time all colonies up to and including those at station G-4 gained weight. On the following day the colonies at the 5-mile station gained weight while those at the more distant stations lost weight. On the ninth day the colonies at station J-6 gained weight. (This coincided with the data of colonies located at the same station in 1927.) The colonies at stations K-7 and N-8.5 did not gain weight during any day of this period.

SECOND PERIOD

In order to demonstrate more clearly the effect of length of flight on the change in weight of certain of the colonies moved, on July 16 some of the colonies from stations G-4, H-5, J-6, and K-7 were moved to stations A-0, B-0.5, D-1.5, E-2, and F-3, as indicated in table 6. One colony (no. 20) was moved from station E-2 to station A-0. This increased the number of colonies under observation at points which seemed to be the most important from the standpoint of practical honey production.

TABLE 6.—*Changes made in the location of colonies at the beginning of the second period, July 17 to 29, 1929, and a comparison between the gains (+) or losses (−) in weight of the colonies in their new locations and in their old locations during the first period*

Colony no.	Old location	New location	Distance moved	Average daily net gain or loss in weight	
				At old location	At new location
			Miles	*Kilograms*	*Kilograms*
20	E-2	A-0	4.0	+1.116	+1.460
37	K-7	A-0	9.4	−.154	+1.599
39	K-7	A-0	9.4	−.152	+1.593
27	G-4	B-0.5	3.5	+.462	+1.006
34	J-6	B-0.5	5.5	−.096	+1.412
36	J-6	B-0.5	5.5	−.079	+.940
26	G-4	D-1.5	2.5	+.214	+.892
29	H-5	D-1.5	3.5	+.050	+1.235
40	K-7	D-1.5	6.5	−.147	+1.459
25	G-4	E-2	2.0	+.375	+.672
28	G-4	E-2	2.0	+.220	+.516
33	J-6	E-2	4.0	−.142	+.569
35	J-6	E-2	4.0	−.166	+.619
30	H-5	F-3	2.0	+.065	+.806
31	H-5	F-3	2.0	+.225	+.336
38	K-7	F-3	4.0	−.153	+1.140

During the forenoon of the day after the colonies were moved, several hundred bees were flying around the spot where station J-6 had been located. Caucasian and Italian bees were present in approximately equal numbers, and most of them were carrying sweetclover pollen. As two of the colonies from station J-6 had been moved at least 4 miles to station E-2, it was evident that some of the field bees, on leaving their hives on the following morning, had flown to the irrigated area, obtained pollen, then returned over the old route to which they had been accustomed, and in so doing covered a minimum distance of 8 miles.

A larger number of bees, most of them bearing sweetclover pollen, were found flying around the place where station H-5 had been. Two of the colonies from this station had been moved 2 miles to station F-3, and one had been moved 3.5 miles to station D-1.5. Still more bees were found clustered on sagebrush or flying around the spot where station G-4 had been; most of them were also carrying sweetclover pollen. Two of the colonies from this station had been moved 2 miles, another 2.5 miles, and the fourth colony 3.5 miles. In gathering pollen and in returning to their old locations, these bees had flown a minimum of 4.5 to 6 miles. In all probability some of the bees from all the colonies moved, with the exception of those moved from

station K-7, returned to their former locations, thus flying minimum distances of from 6.5 to 8 miles.

The bees that returned to the old locations were allowed to enter supers and were taken back to the new locations the same evening. On the second day after the colonies had been moved, bees were flying around the old locations at stations J-6, H-5, and G-4, and they were again returned to their hives. On the following day only a few bees were found flying around the old location of G-4. It is well known that field bees sometimes remain out overnight and return to their hives in the morning. The fact that no bees were found flying around the former location of station K-7 indicates that the field bees did not generally stay out the night the colonies were moved.

During the second period the colonies at all the stations collected sweetclover pollen; those at the first six stations made appreciable gains; while those at station N-8.5 lost weight (table 7). A distance of 1 mile evidently did not appreciably reduce the gain of the colonies, but beyond that point the reduction in gain increased with the distance of flight. This apparent effect of distance may have been accentuated by the fact that more of the field bees from the colonies moved to stations E-2 and F-3 may have been lost than was probably true of the colonies moved to the other station.

TABLE 7.—*Daily average net gain (+) or loss (−) in weight of the colonies at the different stations during the second period, July 17 to 29, 1929*

Station	Colonies	Average gain or loss per colony, in kilograms, on July—												Total of daily average gains or losses in weight	Average daily gain or loss in weight for 13-day period
		17	[a] 19	20	21	22	23	24	25	26	27	28	29		
	Number													*Kilograms*	*Kilograms*
A-0	[b] 7	+1.39	+2.11	+0.99	+1.03	+1.67	+1.46	+1.54	+1.51	+0.90	+0.44	+1.62	+1.48	+16.14	+1.241
B-0.5	7	+1.71	+2.39	+1.21	+.84	+2.12	+1.60	+1.55	+1.89	+.71	+.53	+2.37	+2.06	+18.98	+1.460
C-1	4	+1.87	+2.27	+1.22	+.42	+2.11	+1.75	+1.22	+1.84	+.40	+.51	+2.08	+1.79	+17.48	+1.345
D-1.5	7	+1.53	+1.74	+.88	+.23	+1.82	+1.92	+1.15	+1.91	+.11	+.47	+2.36	+1.91	+16.03	+1.233
E-2	7	+.80	+.97	+.58	−.03	+1.19	+1.63	+.76	+1.21	.00	+.12	+1.87	+1.71	+10.81	+.832
F-3	6	+.89	+1.01	+.41	−.11	+1.00	+1.68	+.53	+1.13	−.03	−.15	+1.89	+1.94	+10.19	+.784
N-8.5	2													−1.74	−.134

[a] No records taken on July 18.
[b] One of the colonies at this station which became queenless during the first period was made queen-right, resumed normal activities, and was thereafter included in the record.

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The effect of moving the colonies nearer to the source of nectar, as shown in table 6, was quite striking in some instances. The greatest difference occurred in those colonies that had been moved from 6 and 7 miles from the source of nectar to within the irrigated area or 1.5 miles from it. These colonies had lost weight during the first period of 1929 but gained when placed in the new locations. In every instance colonies moved nearer to the source of nectar made greater gains than they had in their former positions (table 6) and in several instances they showed greater gains than the colonies already located at the stations to which they had been moved (table 9). These gains were made in spite of the loss of field bees due to the change in locations. It was evident that the colonies at the more distant stations lost weight during the previous period because of the distances that separated them from the source of nectar rather than on account of any insufficiency in the number of field bees.

THIRD PERIOD

The colonies at stations C-1, E-2, and F-3 were moved to stations A-0, B-0.5, and D-1.5, respectively, on the evening of July 29, as indicated in table 8. The same procedure was followed as that used during the previous period, although even greater precautions were taken to see that the bees reoriented themselves in the new locations.

TABLE 8.—*Changes made in the locations of colonies at the beginning of the third period, July 31 to Aug. 9, 1929, and a comparison between the gains (+) or losses (−) in weight of the colonies in their new locations and in their old locations during the second period*

Colony no.	Old location	New location	Distance moved	Average daily net gain or loss in weight	
				At old location	At new location
			Miles	*Kilograms*	*Kilograms*
9	C-1	A-0	3.6	+1.436	+1.325
10	C-1	A-0	3.6	+.888	+.820
11	C-1	A-0	3.6	+1.398	+.654
12	C-1	A-0	3.6	+1.658	+1.358
41	N-8.5	A-0	10.75	−.152	+1.824
42	N-8.5	A-0	10.75	−.115	+1.863
17	E-2	B-0.5	1.5	+1.650	+1.547
18	E-2	B-0.5	1.5	+.806	+1.281
19	E-2	B-0.5	1.5	+1.006	+1.386
25	E-2	B-0.5	1.5	+.672	+.883
28	E-2	B-0.5	1.5	+.516	+.749
33	E-2	B-0.5	1.5	+.569	+1.160
35	E-2	B-0.5	1.5	+.619	+.908
21	F-3	D-1.5	1.5	+.692	+.825
22	F-3	D-1.5	1.5	+.626	+.613
23	F-3	D-1.5	1.5	+.705	+.728
24	F-3	D-1.5	1.5	+.735	+1.174
30	F-3	D-1.5	1.5	+.806	+1.064
31	F-3	D-1.5	1.5	+.336	+.512

Soon after noon of the next day, which was bright and clear, many bees had returned to their old location (station F-3), and by evening 3.4 pounds of bees (approximately 14,000 bees) had collected in the hive placed there to trap them. Most of these bees were loaded with sweetclover pollen and nectar. The colonies from this station had been moved 1.5 miles closer to the source of nectar. Only about one

sixth as many bees from station E-2, which was also moved 1.5 miles closer to the source of nectar, returned to their old location as returned to station F-3. Field bees in much reduced numbers continued to return to their old locations on the second day after the colonies had been moved. These were again collected and taken to the new locations. The third day was a poor day for flight, and only a few hundred bees were found flying around the old location of station F-3. As in the former instances, the returned bees were laden with pollen, much of which was from sweetclover, and with nectar.

The fact that so many bees returned to their former locations was, without doubt, due to the similarity of the entire territory and further to the fact that the bees that returned had evidently worked in the same locations within the irrigated area as they had before being moved. It is possible that other bees may have been lost on the badlands.

The average daily gain of the colonies that were not moved showed practically the same relation to distance as during the previous period (table 9). The average gain of the colonies 0.5 mile from the nectar-producing area was again greater than that of the colonies located within it (table 10).

TABLE 9.—*Average daily net gains in weight of colonies originally located at the stations where consolidations were made, during the 3 experimental periods in 1929*

Station	Average daily net gain, in kilograms, during—			Station	Average daily net gain, in kilograms, during—		
	July 3 to 15	July 17 to 29	July 31 to Aug. 3		July 3 to 15	July 17 to 29	July 31 to Aug. 3
A-0	0.884	1.011	1.006	E-2	0.923	1.154	----------
B-0.5	1.020	1.718	1.507	F-3	.735	.690	----------
D-1.5	.952	1.261	1.148				

TABLE 10.—*Daily average net gain in weight of the colonies at the different stations during the third period, July 31 to Aug. 9, 1929*

Station	Colonies	Average gain per colony, in kilograms, on—							Total of daily average gains in weight	Average daily gain in weight for 10-day period
		July 31	August							
			2	3	5	6	8	9		
	Number								*Kilograms*	*Kilograms*
A-0	13	0.30	2.93	1.71	2.07	1.36	2.17	0.90	11.44	1.144
B-0.5	14	.47	2.97	1.98	2.57	1.57	2.61	.98	13.15	1.315
D-1.5	13	.43	3.47	1.81	1.96	1.05	1.69	.69	11.10	1.110

Table 8 shows that in a majority of cases colonies located at the more distant stations during the second period of 1929 made greater gains in weight when moved nearer the source of nectar. In many instances the average daily gain of such colonies was greater than was that of the colonies at the stations at which the colonies had been consolidated (table 9). In each case the net gain in weight of the colonies was greater at station C-1 than it was after they were moved

within the producing area. This seemed important, as it agreed with the average results obtained in the previous periods.

DISCUSSION OF EXPERIMENTS IN 1927, 1928, AND 1929

The bees from all the stations carried sweetclover pollen during each of the 3 years. The bees at the most distant stations flew at least 8.5 miles before they came to the source of this pollen. Both Caucasian and Italian bees flew this maximum distance.

The average daily net gain or loss in weight of the colonies at the different stations was greater in 1928 than in 1927 or 1929 and also showed more variation between the different stations. These differences cannot be attributed entirely to distance, as some of the colonies at the more distant stations made greater gains than did colonies located at what appeared to be a more favorable distance. The difference was particularly evident between the colonies located at station H-5 and those at station G-4 and was probably due to a difference in the potential or in the actual strength of the colonies at these two stations.

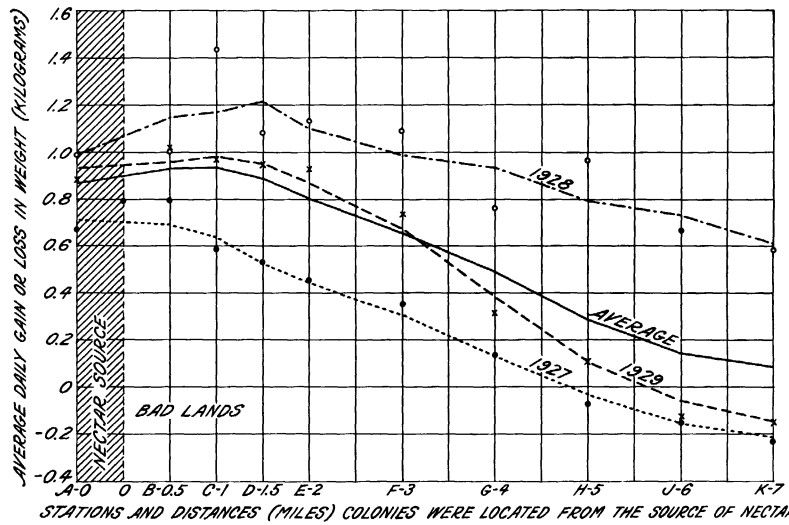

FIGURE 5.—Weight records of the colonies at stations located at known distances from a source of nectar during 1927, 1928, and 1929 in northwestern Wyoming.

The same explanation does not seem to account for the difference in the average daily gain or loss in weight of the colonies within the nectar-producing area and of those located away from the source, as this difference held true during each of the 3 years. The average production of colonies located 1.5 miles from the source of nectar was slightly greater than that of colonies located within the nectar-producing area (fig. 5).

There was a gain of but 0.5 kg (1.1 pounds) in favor of the best Caucasian over the best Italian colony at each of the first 10 stations during the 3 years. This slight difference is hardly indicative of any fundamental difference between the two races in the matter of honey production under the conditions that prevailed during the experiments.

DISTRIBUTION OF HONEYBEES WITHIN A NECTAR-PRODUCING AREA

During the summer of 1930 observations were made on the distribution of bees from apiaries located within nectar-producing areas, to determine, if possible, how far they fly under such conditions and in what manner the bees distribute themselves over the available territory. The observations were made in the San Luis Valley of Colorado and on the plains west of Laramie, Wyo.

The San Luis Valley, with an average elevation of about 7,600 feet, consists of fertile irrigated farming lands devoted to the production of

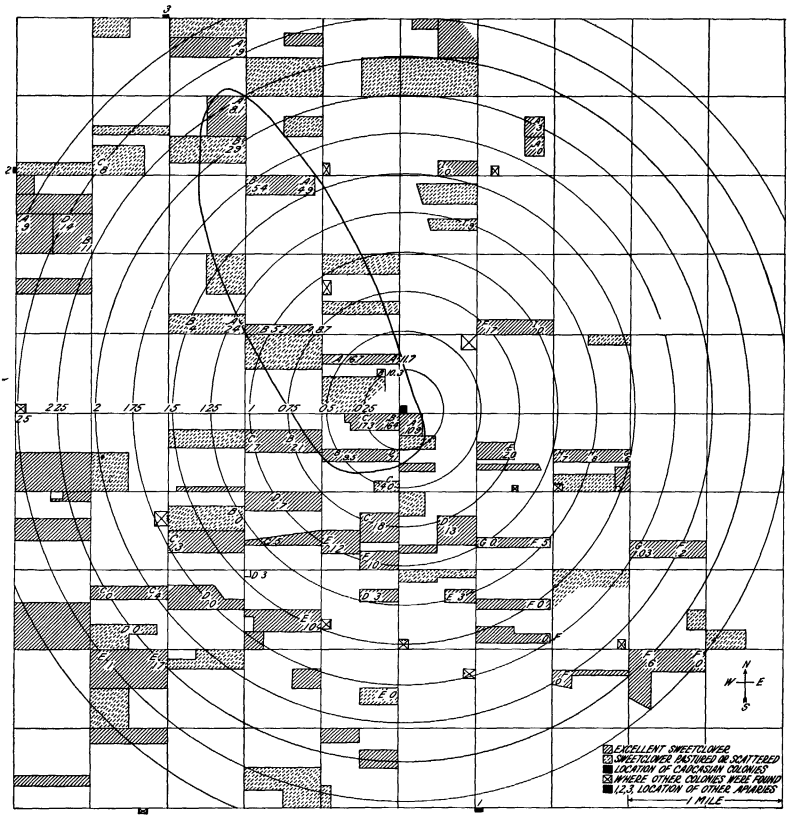

FIGURE 6.—Area in which observations were made on the distribution of bees from a central apiary in the San Luis Valley of Colorado in 1930, showing the average number of Caucasian bees counted in the different sections.

various agricultural crops and to the raising of livestock. Sweetclover is used extensively in the rotation of crops, for hay, pasture, and seed, and forms the principal source of the many carloads of honey annually produced in this valley.

In one section of the valley an area of 25 square miles containing between 2,500 and 3,000 acres of sweetclover was found to be unoccupied by commercial apiaries. Of the few stray swarms found here, all but three were of the Italian race. The location appeared to be not only an excellent place for a commercial apiary but also desirable for carrying on the observations of this experiment (fig.6).

The sweetclover in the many fields varied considerably in height, density of growth, and the stage of bloom during the period of the experiment. Probably 50 percent of the entire stand of clover remained uncut throughout the period in which the observations were being made. Many of the irrigation ditches were lined with a good growth of sweetclover. The fields of clover that had been pastured early in the spring generally came into bloom from 7 to 10 days after the fields that had not been so pastured, and for this reason an attempt was made to indicate in figure 6 the relative importance of the different fields from the standpoint of the density of stand and probable attractiveness to the bees. The fields that were pastured by sheep did not come into bloom until after the bees from the experimental apiary had oriented themselves in relation to the area as a whole.

The location west of Laramie, Wyo., where observations were continued after the close of the work in the San Luis Valley, had a

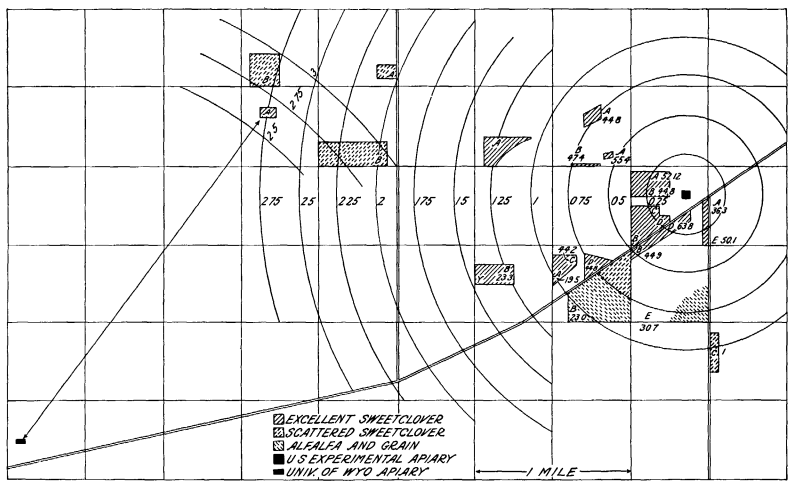

FIGURE 7.—The area in which observations were taken on the distribution of bees from the experimental apiary of the intermountain bee culture field laboratory, near Laramie, Wyo., in 1930, together with the average number of bees counted in different portions of the area. Y at the 1.5-mile point indicates a station at which observations were made, but at which no bees were found.

much more limited range of pasturage, as can be seen readily by comparing figures 6 and 7. The greater portion of this territory, however, was visited almost exclusively by bees from the experimental apiary, consisting of 42 colonies, and from a smaller apiary of 11 colonies situated about 4.5 miles away. The bees from these two apiaries, which were about 2.5 miles apart, worked to a slight extent in the intervening fields of sweetclover.

Since all the stray swarms found within the area in the San Luis Valley and within flying distance of it were Italian bees, with the exception of the three colonies of Caucasian bees mentioned, which were disposed of, it was decided to establish an apiary of Caucasian bees in the center and to use the natural color of the bees as an aid in making the observations. Accordingly, an apiary of 58 colonies, in which most of the bees were well-marked Caucasians, was established in the central position indicated in figure 6. All colonies were manipu-

lated as little as possible and were provided with ample storage space at all times.

To determine the direction of the flight of bees from an apiary, one or more observers walked around it at a distance great enough that the sound made by the bees in the apiary could not be heard. By walking slowly, stopping every few feet to listen for the sound of flying bees and to watch the direction of their flight, it was possible not only to determine the directions in which the bees flew, but also to estimate the relative number flying in any direction.

To determine the distribution of the bees over any given area, three observers took counts of bees as they walked slowly through previously designated fields of sweetclover for a given period of time. Through practice gained by the observers working together before the observations were started and several times during the experiment, it was found that, with the aid of hand tallies, each observer could count the bees in an area approximately 6 feet wide by 60 paces long during a 5-minute period. The observers were assigned to different sectors so that each covered the entire area under observation at one time or another. This procedure tended to equalize the personal equation. The observers took records at the same distances from the apiary and also at the same time, assuring thereby that the observations made at the various distances from an apiary were under identical conditions.

Bees were also marked in the fields with distinctive colors for later identification.

No records were made on days when the wind was blowing, as it was found that bees could not be counted accurately when the sweetclover plants were swaying to any great extent. As the afternoons were generally windy, the counts were for the most part made in the forenoons.

OBSERVATIONS IN THE SAN LUIS VALLEY

The observations taken in the San Luis Valley brought to light much information not anticipated before the work was started. The bees from the experimental apiary oriented themselves the morning after they were established, but no observations were recorded for several days. Most of the sweetclover fields were in good bloom at the time the bees were placed on location. It was soon evident, however, that in spite of the fact that good fields of sweetclover were available on at least three sides of the apiary, with the best fields situated in a southwesterly direction, the bees flew quite generally in a northwesterly lane of flight.[5] A second lane of flight was in a southwesterly direction, while comparatively few bees flew in the other direction.

The data in table 11 and figure 6 indicate that the greatest concentration of bees occurred in the fields adjoining the apiary to the west and northwest and was pronounced for a distance of 0.25 to 0.5 mile. The concentration of bees seemed to be greater in field B, which was adjacent to the apiary on the southwest, than in field A, also adjacent but southeast of the apiary. Only a comparatively few bees were ever found working in the fields southeast of the apiary. The greatest

[5] The term "lane of flight" denotes the direction and manner in which bees fly from an apiary. It is used by many beekeepers, especially in the commercial beekeeping area of the Rocky Mountain region, in a broader sense than the term "line of flight" implies. The latter term is used most frequently to denote the direction and flight of individual bees, or of a swarm, whereas the former denotes the flight of many thousands of bees flying more or less independently but in the same general direction over a narrow angle from the apiary. The two terms are used somewhat synonymously.

concentration of bees was found 0.25 mile west of the apiary, where on an average 17 bees were counted during each 5-minute period. The next greatest concentration occurred in the field 0.5 mile northwest of the apiary (A-0.5). Bees were found in greater numbers in each of five fields northwest of the apiary than in any other fields. The bees were also found to have flown as far as 2.75 miles northwest from the apiary, 2.5 miles southwest, and 2.25 miles to the southeast. The fact that there were at least 1,100 acres of sweetclover in the southwestern quarter of the area, 930 acres in the northwestern quarter, only 220 acres in the northeastern quarter, and approximately 430 acres in the southeastern quarter had little effect on the density of the distribution of the bees.

TABLE 11.—*Distribution of bees in the San Luis Valley of Colorado, in the area shown in figure 6*

Quarter	Station	Counts	Bees	Average bees per count	Quarter	Station	Counts	Bees	Average bees per count
		Number	*Number*	*Number*			*Number*	*Number*	*Number*
Northeastern	F-0.75	7	12	1.7	Northwestern	B-2	12	35	2.9
	I-1	9	0	.0		B-2.25	9	10	1.1
	I-1.25	8	7	.9		A-2.25	11	89	8.1
	I-1.5	9	5	.6		A-2.5	7	13	1.9
	A-1.75	6	0	.0		B-2.5	1	5	5.0
	A-2	6	2	.3		C-2.5	8	6	.8
Southeastern	A-0	26	284	10.9		D-2.5	15	21	1.4
	E-0.75	4	8	2.0		A-2.75	13	12	.9
	D-0.75	8	10	1.3		B-0	16	362	16.4
	G-1	3	0	.0		C-0.25	23	399	17.3
	H-1	9	4	.4		D-0.25	23	164	7.1
	E-1.25	4	1	.3		B-0.5	22	209	9.5
	F-1.25	2	1	.5		C-0.5	8	32	4.0
	G-1.25	2	0	.0		B-0.75	17	36	2.1
	H-1.25	6	5	.8		C-0.75	8	14	1.8
	F-1.5	3	0	.0		C-1	10	7	.7
	G-1.5	7	4	.6		D-1	6	4	.7
	F-1.75	4	0	.0		E-1	6	7	1.2
	G-1.75	26	1	<.1		F-1	4	4	1.0
	E-2	4	0	.0	Southwestern	B-1.25	3	0	.0
	F-2	6	1	.2		C-1.25	2	1	.5
	F-2.25	8	5	.6		D-1.25	4	1	.3
	F-2.5	9	0	.0		D-1.5	12	3	.3
Northwestern	A-0.25	23	270	11.7		E-1.5	4	4	1.0
	B-0.25	4	41	10.3		C-1.75	3	1	.3
	A-0.5	29	483	16.7		D-1.75	5	0	.0
	A-0.75	23	200	8.7		E-1.75	4	0	.0
	B-1	25	129	5.2		C-2	8	3	.4
	A-1.25	5	12	2.4		C-2.25	2	0	.0
	A-1.5	33	161	4.9		D-2.25	4	0	.0
	B-1.5	5	2	.4		E-2.25	6	1	1.7
	B-1.75	33	178	5.4		E-2.5	8	1	.1

The data in table 11 and figure 6 show that beyond a 0.5-mile radius the bees distributed themselves principally in one direction.

The hives in the experimental apiary were located in the southwestern corner of a sparsely wooded pasture and faced south. Adjacent to the apiary at the southwest stood a small group of trees which seemingly did not interfere with the flight of bees. The general direction of the prevailing wind was from the southwest, although at different times it shifted to all other directions. Italian bees were found in all fields in which observations were made, but apparently never in sufficient numbers to be a factor in excluding other bees. No explanation in regard to landmarks, character of the fields, or climatic factors could be found to account for the way in which the

bees distributed themselves in relation to the area as a whole, although the fact that the fields of sweetclover which had been pastured, such as those in which stations B-1.5 and A-1.25 were located, did not come into bloom until after the bees had become oriented undoubtedly was responsible for the low counts.

In another portion of the San Luis Valley a number of apiaries were located in fairly close proximity to one another (fig. 8). As the bees from the experimental apiary mentioned above had not distributed themselves in all directions over the available territory, it

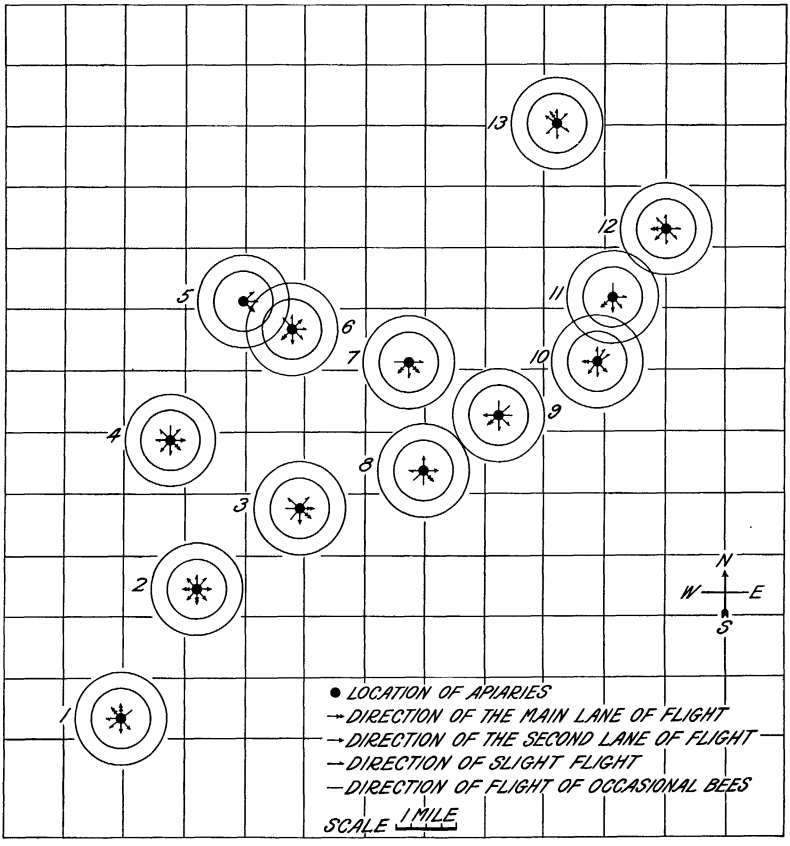

FIGURE 8.—Relative location of 13 apiaries in the San Luis Valley of Colorado, showing the directions in which the bees flew from each apiary.

was thought that a determination of the directions in which the bees flew from the apiaries in another part of the same valley might give some additional information on the distribution of bees when located within a good nectar-producing territory.

It was found that the bees from 9 of the 13 apiaries had only one major lane of flight, and that of the remaining 4 the bees from only 2, nos. 2 and 7, were flying in major lanes of flight that were in different directions. Bees from only two apiaries, nos. 11 and 5, were trespassing within a radius of 1.5 miles in the territory of the major lane of flight of apiaries 10 and 6. In the case of apiary 5 the main

flight went directly over and slightly to one side of apiary 6, so that the bees from apiary 5 were actually working in a territory southeast of apiary 6. The bees from apiary 9 were apparently concentrating their efforts in an area lying between them and that of apiary 8, but as the bees from the latter were flying mainly in another direction the two flights did not cross. In only a few instances, and particularly in the case of apiary 2, were the bees of any apiary taking full advantage of their location, as judged by the directions in which they were working in relation to the fields of sweetclover that surrounded them.

The direction of the prevailing winds appeared to have no definite relation to the principal directions in which the bees were flying from the different apiaries. As the directions of flight evidently depended on a major source of supply to which the bees had oriented themselves at the time the plants came into bloom, it is only reasonable to suppose that the direction of flight would depend on a continuance of the nectar flow in that direction. If for any reason the source of food was reduced or if a better source of nectar was discovered in another direction, the direction of flight might be changed accordingly.

Such a contingency was investigated by the writer during the summer of 1929. For some unexplained reason, at certain times nearly every summer bees from a commercial apiary near Worland, Wyo., were in the habit of leaving a fertile valley in which they were located to fly over a stretch of badlands to a much smaller valley and bring back nectar in quantity and quality similar to what they had been gathering. The distance across the badlands was 4.6 miles. On other occasions, however, the bees had been observed to fly in a slightly different direction, making the distance covered even greater. In order to leave the valley in which they were located, the bees had to fly over a steep rise of land that was estimated to be at least 150 feet higher than the apiary. The badlands were extremely rough, there was no source of water or nectar between the two valleys, and the flight was not in the direction of the prevailing winds.

OBSERVATIONS NEAR LARAMIE, WYO.

As stated previously, the nectar-producing flora in the vicinity of the apiary west of Laramie, Wyo., belonging to the intermountain bee culture field laboratory, was much more limited than that in the San Luis Valley of Colorado; consequently, the observations were confined to a smaller area (fig. 8). The distribution of the bees was found to be somewhat uniform within a radius of 0.75 mile, but beyond this distance the number of bees found in any field decreased considerably, as did also the available sources of nectar. Field A-1.25 and the greater portion of B-1.5 were cut for hay soon after the observations were started. Field B-2 was in good bloom but consisted of very short clover that had not been irrigated and, although it was examined on several occasions, no bees were ever found there. Only a few bees were found in field A-2.75 and in B-2.75, but most of these were shown to have come from the apiary of the University of Wyoming, 2.5 to 2.75 miles to the southwest.

As the colonies in this location were stronger than those in the experimental apiary in the San Luis Valley, the results of the two sets

of observations cannot be compared directly. Possibly this factor, plus the restricted territory of the Laramie location, was responsible for the noticeable increase in the numbers of bees found working in the areas under observation.

DISTRIBUTION OF MARKED BEES

A number of bees were marked distinctive colors in each of the 3 fields in the San Luis Valley and in 3 fields west of Laramie, in an attempt to identify the colonies from which they came and thus to establish the distances they flew, and also to learn whether the same bees return to the same fields on successive days.

In field D-1.5 in the San Luis Valley 150 bees were marked with a green dot. On four successive days thereafter green-marked bees were found in the same field. A beekeeper told the writer that he had found 2 green-marked bees in his apiary 2.5 miles southeast of this field 2 days after the bees were marked. No green-marked bees were ever found in the experimental apiary.

In one corner of a much larger field, B-1.75, 190 bees were marked another color. Over a period of 12 days thereafter some of these marked bees were found working in the same small corner of the field in which they were marked. During the same period 12 bees with the same markings were found in the experimental apiary, and 1 was found working in field A 7 days after the first bees were marked.

In a third field, A-2.25, 10 bees were marked still another color and, although none of these were ever found again in the same field, 4 of them were seen in the hives of the experimental apiary on the third, sixth, and eighth days after they were marked.

In an effort to determine from which apiary the bees came that were found working in field A-2.5 (fig. 7) near Laramie, 126 Caucasian and 42 Italian bees were marked in that field. Two days later, when only a few bees were working, 3 marked bees were seen in the same field. On the following day 1 of the marked bees was found in the apiary connected with the intermountain bee culture field laboratory and 47 in the apiary belonging to the University of Wyoming. These 47 bees were scattered in 10 of the 11 colonies in this apiary, although in 1 colony 25 marked bees were counted.

In another small field located beyond the flying range of these 2 apiaries but within 2.5 miles of 5 other apiaries, which ranged from 6 to 37 colonies in size, 827 bees were marked. During a 30-minute examination of this field on each of 2 successive days thereafter, 36 marked bees were observed out of a total of 493 bees counted. The colonies in the 5 apiaries were then searched, with the result that marked bees were found in each apiary, and a total of 127 marked bees were located (table 12). Although 7 colonies of bees were found in the field in which these bees were marked, only 22 marked bees were recovered in these colonies, in contrast to 31 in the same number of colonies 0.5 mile west of the field. In another apiary 2.25 to 2.5 miles distant, from which the bees had to fly over the city of Laramie, Wyo., as well as over a mile or more of other territory, in order to reach the small field of clover, 5 marked bees were recovered.

TABLE 12.—*The distribution of bees from 5 apiaries in relation to a small field in which 827 bees were marked*

Distance of apiaries from field (miles)	Colonies in apiary	Colonies examined	Colonies with marked bees	Bees found in each colony (number)	Total marked bees found
	Number	*Number*	*Number*		*Number*
Same field	7	7	7	6, 4, 2, 2, 3, 2, 3	22
0.5	7	7	7	1, 6, 2, 6, 4, 6, 6	31
0.75	43	37	11	1, 1, 1, 1, 1, 3, 1, 1, 1, 2, 1	14
1.25 to 1.5	29	23	9	1, 12, 3, 1, 28, 1, 4, 3, 2	55
2.25 to 2.5	7	6	3	1, 2, 2	5

SUMMARY

Estimates of various writers have placed the flight range of honeybees at distances of from 1 to 7 or more miles, but little experimental evidence has been presented. It is also generally believed by beekeepers that bees will fly in all directions from an apiary in quest of nectar and pollen. Regulations governing the location of apiaries in respect to the control of bee diseases, from the viewpoint of honey production, and to prevent bees from becoming nuisances, vary widely in their requirements owing to differences in the assumed distances that bees can fly.

When colonies were located on a prairie in Wyoming, during a dearth of nectar, it was found that the bees would fly but 1.5 miles for artificial stores and at least 3 miles for pollen and nectar.

When bees were separated from a given nectar-producing area by the badlands, with no other source of food intervening, they flew a maximum distance of at least 8.5 miles. Colonies located within 0.5 to 2 miles of a given source of nectar made gains in weight, over a period of 3 years, as great as, or greater than, similar colonies located within the same nectar-producing area, and colonies lost in weight when placed 5 miles or more from nectar.

When colonies were moved for varying distances up to 3.5 miles, many bees went to the fields and then returned to their former locations. The return of such bees was undoubtedly influenced by the fact that the colonies had been moved into surroundings that were similar to their former locations and also by the fact that the bees worked in the same territory in which they had worked before being moved.

Experiments on the distribution of bees from apiaries located within a nectar-producing area showed that bees have a tendency to fly in only one or two major lanes of flight, neglecting similar forage plants in other directions. Bees would fly for 2.75 to 4.6 miles in one direction when located within a nectar-producing area and confine their efforts to working in that direction rather than in nearer fields of seemingly equal attractiveness. In one series of observations, bees were found to work most numerously in fields located within 0.5 mile of their apiary. Where several apiaries were located within the same general territory, the major lanes of flight from the different apiaries did not indicate so much trespassing of the bees from any one apiary on the territory of another as might be expected from the proximity of their locations. Where the nectar supply was limited, bees from

several colonies in each of five apiaries worked in the same small field, some of the bees flying at least 2.5 miles to reach the field in question.

The results confirmed the conclusions of previous investigators that bees have a tendency to return to the same portion of a field, or to the same small field, on successive days for nectar and pollen, even though other areas of the same forage plant are nearer.

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