Bulletin 391 July, 1932

RED-CLOVER POLLINATION BY HONEYBEES IN COLORADO

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RED-CLOVER POLLINATION BY HONEYBEES IN COLORADO

By R. G. Richmond*

Reports have been current in the Rocky Mountain region, of large yields of seed from red clover *(Trifolium pratense* L.*)*. Some of these reports have come from the irrigated strip of land bordering on the Arkansas river in Colorado, and chiefly from the vicinity of Rocky Ford. Yields have been known to exceed 14 bushels of seed per acre and to reach even 18 bushels. This yield is obtained from two cuttings per year. By far the greater seed crop is reported from the first cutting.

Accompanying these reports of large yields, comes information that honeybees have been very prevalent on the blooms, indicating that they have possibly had a part to play in the setting of the large seed crops.

In view of these stories of large seed crops, it was decided to investigate the role of the honeybee *(Apis mellifica* L.*)* in red clover pollination at various points in the state.

Review of Literature

In an article by the writer (19), attention was directed to the dearth of bumblebees and the large number of honeybees on the first crop of red clover, in Colorado.

It was also mentioned that little nectar seemed to be present in the florets.

Reference has been made by other writers, to the yields of seed in other localities, with speculations, in some cases, as to the cause of the variation of seed yield. Aicher (1) points to exceptionally heavy yields reported from various points in Southern Idaho. These reports indicate seed crops of from 9 to 15 bushels per acre. It is not mentioned by this author if the reported yields are from one or two cuttings. Other authors less optimistic, refer to the usually light yields from the first crop. Hunter (12) says experience has taught the clover-seed producers that the first crop, especially that of red

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The completion of this work in 1930 was conducted as part of a cooperative project with the U. S. Bureau of Plant Industry. Acknowledgments are herewith extended to Dr. E. A. Hollowell for kindly suggestions.

Figure 1.—A normal field of red clover in Colorado.

clover, yields a very small quantity of seed if allowed to mature naturally. Martin (14) speaks of the usually poor seed production in the early part of the season. Hunt (11) bears out the opinion of Martin, in a statement that,

"The most abundant seed is obtained from plants that do not grow so large as to be blown down or become decumbent on account of their great weight. This dry soil is therefore most suitable to the seed crop. Throughout the North Atlantic and North Central states, only the second crop is cut for seed, since the first crop seeds less abundantly than the second. Two reasons for this have been offered. First, since the second crop is not so luxuriant as the first, it is less likely to fall down from wind and otherwise; and second, the first crop is usually harvested before bumblebees become abundant. The writer had a late blooming first crop examined, bumblebees having by that time become common, and found an abundance of seed."

Hopkins (10) observes that there may be as much seed set in the first crop as in the second.

Noting another angle of the extent of seed production, Hollowell (9) points out that it must be bourne in mind that under field conditions an average of 25 seeds per head is considered to assure a fair seed crop.

Work has been presented showing the effect of atmospheric and soil-moisture conditions during pollination and setting of seed. Aicher (1) observes that pollination and fertilization take place most rapidly when blossoms are dry and when the atmosphere is both dry and warm. Hollowell (9) after conducting some hand-pollinating experiments notes that the results show that high atmospheric moisture in both field and greenhouse did not limit the setting of red-clover seed. Martin (14) speaking of conditions modifying the amount of water delivered by the stigma having an effect on fertilization says,

"This may account for the usually poor seed production in the early part of the season, since there is usually more moisture in the ground at this time and more rain during the flowering period than occurs during the second crop." This author does not state if insect pollinators are as plentiful on the first as on the second crop and the first seed crop is inferior in quantity to the second, the problem may be physiological, otherwise it would appear to be entomological.

Many demonstrations have been made as to whether red clover be self sterile or otherwise. It will suffice to mention representatives of these. Cook (6) covered 10 heads of red clover with cheesecloth to prevent insect visitation. No seed set, while on 10 other uncovered heads of the same age, 191 seeds set. Bolley (5) investigating the same point, screened a large area of red clover with wire screen of so small a mesh that nothing larger than a mosquito could well penetrate. Only one red-clover head produced seed and that but one or two kernels. Beal (3) found a few seeds in caged heads during each of his 8 years' observations. Westgate and Coe (25) showed why red-clover flowers are almost completely self sterile.

Much has been written on the value of bumblebees as pollinators of red clover. Root (20) comments that as agents in the pollination of flowers, bumblebees are second only in importance to honeybees Many flowers are adapted wholly to their visits. Several flowers, including red clover, are mentioned by this author. Washburn (26) proved that bumblebees pollinate red clover. Waldron (23 and 24) concludes that bumblebees are responsible for about 95 percent of the red-clover seed produced. Pammell and Kenoyer (16) did not place much confidence in the honeybee as an effective pollinator under all circumstances.

Schneck (21) states that *(Xylocopa virginica),* the Virginian carpenter bee, slits the corolla tube of red-clover flowers to obtain the nectar. This author also avers,

"I have repeatedly observed the honeybee (*Apis mellifica* L.) visit all these plants, and it apparently prefers to take the nectar through the

slits that have been made by the carpenter bee; but when it does not find a slit already made it then goes to the mouth of the tube and visits the flower in the usual way, by entering the mouth of the tube."

It is said that nectar is freely secreted by red clover. This conclusion has been so general in acceptance that, some years ago, efforts were made to select and breed a race or strain of honeybees of tongue length adequate to make red-clover nectar readily accessable. Pammell and Kenoyer (16) observed that on pulling the red-clover flower out of the calyx, the nectar is visible to the naked eye. Pellett (18), discussing nectar secretion in red clover, observes that there is no question but that the plant secretes nectar in abundance. The same author quotes many beekeepers who insist that they have secured varying crops of red-clover honey. However, no conclusive evidence is put forth that the honey in question was from red clover. Too, this author's statement, regarding the abundance of nectar in red clover, does not necessarily apply to all localities where the plant grows commercially.

Referring to previous comment on the tongue length of honeybees, it is noted that comparisons have been made between tongue length of honeybees and the length of the corolla tubes in red-clover flowers. In respect to tongue length, Mikhailoff (15) reports some biometry of the honeybee, quoting several Russian investigators. The longest tongue found by any was 6.875 mm., including mentum, submentum and ligula (glossa). The average length of proboscis found by this author was 6.6023 mm. Alpatov (2), measuring 15,000 bees, finds few with longer tongues than those mentioned by the previous author. The longest-tongued bees found in the United States were the Caucasians of Colorado. No variation in tongue length was found from south to north, due apparently to their conglomerate origin. It is well to note here, that few of the bees in the Arkansas Valley are of other than the ordinary Italian cross of the state. Gillette (7), speaking of measurements of tongues of 230 bees from various parts of the country says,

"I shall have to conclude that, so far as my study of the subject has gone, there has been no indication of any strain of common honeybee worthy of the distinction long-tongued. These measurements do not disprove that there may be strains of bees that work more fully than others upon red clover." Going further and comparing the length of the corolla tubes and the length of the bees' tongues, this author wonders if it is possible that those who think bees have gathered honey from red clover can be mistaken, and that they visit the blossoms of this plant for pollen only. At the time of this author's investigation,

breeders were advertising queens which were supposed to produce a long-tongued or red-clover strain of bees.

PROCEDURE

In investigating this problem, it seemed logical to ascertain first if bees, working on red clover, were carrying pollen. While casual observation proved that pollen was carried, determination of the percentage of bees with loads of pollen was thought advisable. Also, some notation was made regarding the tendency of bees to carry pollen and nectar on the same fielding trip.

At the outset of the problem, efforts were made to discover if honeybees were a major or a minor factor in red-clover pollination at Rocky Ford. Cages were made of screen wire to cover plots of clover for different purposes. The screen used was of 13 meshes to the inch, adequate to prevent the passage of common honeybees or bumblebees.

A large cage, 20 feet by 10 feet and 10 feet high, was constructed to include a colony of honeybees. This cage was placed before clover-blooming time, or if blossoms were present, they were plucked before the bees were placed in the cage. The bees were left in the cage during the large part of the blooming period. (A colony, in such a position, rapidly looses its strength and should have a frame of capped brood added as needed.)

Smaller cages, 5 feet by 5 feet and 2.5 feet high, were made and placed over areas not yet in bloom or from which the blooms were plucked. These cages were used to exclude all insects unable to penetrate the screen above mentioned.

Another pair of cages, 6 feet by 6 feet and 34 inches high, were put in operation at Fort Collins. These were used to determine the pollinating effect of night-flying insects. The plots, covered by these cages, were uncovered, one during the day and one during the night, during part of the major blooming period.

At a later date, seed counts were made from the flowers in the cages and in the open field. Analyses were made of the seed to test its viability and to demonstrate the type of seed counted. To check the percentage of seed set per flower, counts were made of the number of flowers per head. The general condition of the flowers was observed as to the ideal pollinating time, whether it be before flush pollinating time, at time of flushest bloom, or during the early withering stage of the corolla. Notes were made as to the presence of nectar and regarding the length of the corolla tube.

It was thought that there might be competition between red clover and other plants for the attention of insect visitants. Gubin (8), reporting on the work of Klingen and Lisitzin, states that these workers conclude that the successful fertilization of red clover depends on: First, the absence at the moment of the blooming of the red clover of any competition with other nectar-secreting plants, and second, the cultivation of long-tongued Caucasian bees. Information was sought to determine if the presence of alfalfa in bloom, seemed to detract from the attention of bees to red clover, alfalfa being the main bee plant in flower during the early part of the first cutting red-clover bloom. Clover heads, which had bloomed and browned before alfalfa started, were tagged. Some, in flush bloom just before alfalfa was cut, were marked. Seed counts were made from these heads at maturity.

OBSERVATIONS

BEES CARRY RED-CLOVER POLLEN.—Honeybees were collected from a red-clover field by two methods. A sweeping net was used to collect a few but was discarded. The danger of collecting bees with pollen loads from other plants, was recognized. Hand picking of bees from clover heads was thought more accurate. In a collection of 111 bees, 104 or 93.7 percent were found, upon microscopic examination, to have pollen in their baskets. In another group of 66 bees, 65 or 98.5 percent were carrying pollen. These bees were taken as noted on the clover heads and without selection. The high percentage of bees with pollen in their baskets seems remarkable, in that some bees are constantly coming and going to the hive. Too, some bees escaped the operator in his effort to apprehend them. Possibly these bees were less loaded and more able to make a speedy escape than those which carried loads. But, since a small percentage escaped, the error in the above figures is slight. It is well to note, regarding pollen-carrying bees, observations by Soudek (22), who says,

"The bees seemingly after they become collector they start first with collecting pollen and later with nectar and water." The remark of this author would seem to be borne out by the observations of the writer, as mentioned above. The large percentage of bees carrying pollen was not because of a dearth of nectar, as a colony within one-half mile averaged 3.4 pounds per day net gain, from sweet clover and alfalfa, over a period of 10 days at the time the bees were taken on the red clover.

It is not the intention of the writer to imply that bees do not carry nectar and pollen at the same time. The facts are to the contrary. The work of Soudek (22) does not state that bees adhere rigidly to one job at one time, but indicates that there is a tendency so

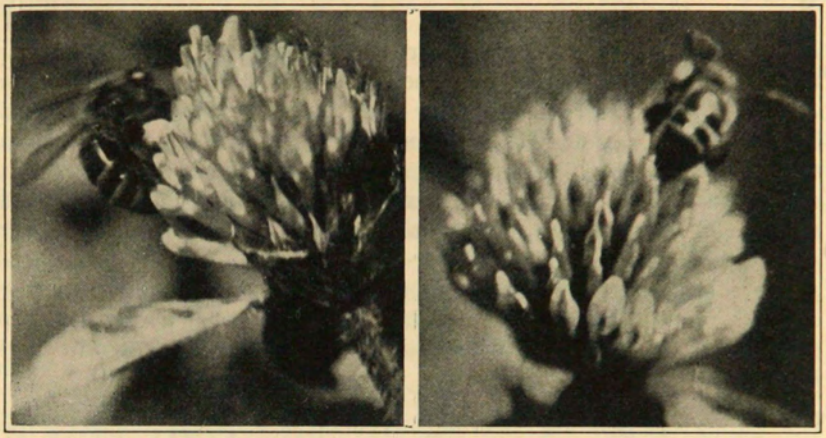

Figure 2.—Honeybees at work pollinating red clover. Note the pollen on the legs in the picture to the right.

to do. Observations by the writer showed that bees were carrying large loads of sweet-clover nectar and also loads of pollen. Lazenby (13) states that he has killed scores of pollen-bearing bees just as they were entering the hive and has never found one loaded with more honey than one is likely to find in any worker bee when it leaves the hive. This author does not state what plants were in bloom at the time or if any honey flow was in progress during the investigation.

While it may be questioned that the pollen on these bees was from red clover, it probably was from that source. Betts (4), after careful examination of about 1500 pollen samples, found that 6.75 percent were loads of two or more kinds of pollen. This finding corresponds closely to that of another investigator whose work is as yet unpublished. It is also pointed out by Parker (17) that honeybees are specifically constant in their pollen gathering.

It should be bourne in mind that, during this investigation, bees were very plentiful on red clover. During the first-crop blooming-time they were found, on sweeping with a net, to outnumber the bumblebees more than 100 to 1. Casual observations, in undisturbed areas of clover, bear out this ratio. Pollen seemed very plentiful and was carried in large loads. The abundant supply of pollen in red clover is mentioned by Hopkins (10).

Bearing in mind these observations and noting information in a later part of this paper, it seems well to question here, the reason for the visit of the honeybee to the red-clover flowers. According to Parker (17), *Trifolium pratense* is listed as a plant from which "pol-

len only'' was secured. Do the bees find therein a source of pollen more convenient than elsewhere? Some other localities have a poor set of seed in the first crop according to Hunter (12) and Martin (14). Can it be that, in such localities in some seasons, there are sources of pollen more desirable or more accessible than are furnished by red clover? Under Colorado conditions, the theory presented in these questions seems more tenable than any presented thus far. It would seem logical that the presence or accessibility of nectar need not be the factor which governs the visits of the bees to red clover any more than the availability or desirability of various sources of pollen. It seems as logical that bees would seek out pollen, in case of need, just as they hunt for nectar when it is needed. Evidence to corroborate this opinion is found in the fact that honeybees visit freely staminate flowers.

CAGES GOVERN POLLINATORS.—The large cage, as described under procedure, had a colony of ordinary honeybees placed therein late in May, when the clover blooms were well advanced. Most of the field bees (pollen and nectar gatherers) flew to the screen and did not return to the hive. These bees took little, if any, part in the pollination of the caged clover blossoms. The colony was distinctly weakened by these fielders being lost. Despite the weakened condition of the colony a good set of seed was obtained. Five hundred heads were picked from the cage the first week in July. Fifty heads were taken at random from this group and threshed. Care was taken to discard any head that had been damaged in picking or shipping. These fifty heads yielded 3077 seeds or 61.54 seeds per head. Only plump, undamaged seed was counted. A small percentage of seed was lost in all counts due to clover seed chalcid *(Bruchophagus funebris* How.) injury. The maximum number of seeds from one head was 133 and one seed was the minimum.

From the small cages, used to exclude insects, 500 heads were picked and treated as those above mentioned. From this group 100 heads were taken and were found to contain 49 seeds, an average of .49 seeds per head. It is possible that these seeds came from heads which had grown against the screen of the cage. Bumblebees had been observed at work on such heads thru the screen.

From the open field, where pollinators could visit at will, 200 heads of clover yielded 13,452 seeds, an average of 67.26 seeds. In another group of 150 heads, 13,984 seeds averaged 93.23 seeds per head. These records are from two seasons.

Similar results to the above were obtained by Mr. Justus Ward in 1928. No seed set where pollinators were excluded, .0729 grams

Table 1.—Showing corolla measurements in mm., flowers per head and seed set per head, in Field No. 1, at Rocky Ford, 1927.

Corolla Measurements						Flowers Per Head				Seed Set Per Head			
Head No.	Tube length 1	2	3	Flower No. 4	5	Head No.	Flowers	Head No.	Flowers	Head No.	Seed	Head No.	Seed
1.	11	11.5	12.5	12	10.5	1.	101	26.	119	1.	100	26.	129
2.	11	10.5	10.5	11	10	2.	100	27.	96	2.	134	27.	80
3.	10	10.5	9.5	10	10	3.	99	28.	78	3.	122	28.	82
4.	9.5	9.5	9.5	10	10	4.	115	29.	73	4.	123	29.	118
5.	10	10	10	10	10	5.	118	30.	103	5.	91	30.	96
6.	10.5	10.5	10.5	10	10	6.	81	31.	161	6.	70	31.	105
7.	10	9.5	9	9.5	10	7.	97	32.	133	7.	36	32.	111
8.	11	11	11	11	11	8.	119	33.	109	8.	78	33.	103
9.	11	11	11.5	11.5	11	9.	97	34.	80	9.	109	34.	77
10.	11	11.5	10.5	11	11	10.	119	35.	102	10.	101	35.	123
11.	11.5	11.5	11.5	11.5	11.5	11.	119	36.	66	11.	37	36.	63
12.	10.5	11	10.5	10.5	10.5	12.	117	37.	119	12.	130	37.	95
13.	10.5	10.5	11	11	11	13.	70	38.	101	13.	89	38.	71
14.	11	10.5	10.5	11	11	14.	92	39.	80	14.	70	39.	55
15.	10	10	9.5	10	10	15.	76	40.	88	15.	100	40.	71
16.	10.5	11	10.5	10.5	11	16.	86	41.	114	16.	100	41.	68
17.	11	11	11.5	11.5	11.5	17.	73	42.	86	17.	83	42.	73
18.	10	10	10	10	10	18.	109	43.	74	18.	126	43.	109
19.	12	12	12	12	12	19.	102	44.	100	19.	81	44.	91
20.	10	10	10.5	10.5	10.5	20.	110	45.	125	20.	61	45.	68
21.	10.5	10.5	10.5	10.5	10	21.	118	46.	83	21.	84	46.	78
22.	10.5	10	10.5	10.5	9.5	22.	99	47.	97	22.	71	47.	65
23.	11	11	11	11	11	23.	128	48.	74	23.	105	48.	89
24.	10	10	9.5	10	10	24.	78	49.	120	24.	68	49.	79
25.	11	11.5	11.5	11	11	25.	84	50.	135	25.	89	50.	91
Mean	10.6±.04 mm.					Mean	100.46±1.87			Mean	88.96±2.2		
Max.	12.5 mm.					Max.	161			Max.	134		
Min.	9.0 mm.					Min.	66			Min.	36		

Table 2.—Showing corolla measurements in mm., flowers per head and seed set per head, in Field No. 2, at Rocky Ford, 1927.

Corolla Measurements						Flowers Per Head				Seed Set Per Head			
Head No.	Tube length 1	2	3	Flower No. 4	5	Head No.	Flowers	Head No.	Flowers	Head No.	Seed	Head No.	Seed
1.	9.5	10	10	10	10	1.	113	26.	92	1.	111	26.	134
2.	9	9.5	9.5	9	9.5	2.	107	27.	118	2.	166	27.	100
3.	10.5	10.5	10	10.5	10	3.	150	28.	112	3.	109	28.	119
4.	9.5	9.5	9.5	9.5	9.5	4.	78	29.	115	4.	79	29.	73
5.	10	10	10	10	10	5.	119	30.	140	5.	78	30.	90
6.	10	10	10	10	10	6.	99	31.	128	6.	78	31.	88
7.	10.5	10.5	10	10.5	10.5	7.	123	32.	112	7.	77	32.	96
8.	10.5	10	10	10	10	8.	106	33.	127	8.	133	33.	88
9.	10.5	11	11	11.5	10.5	9.	121	34.	101	9.	78	34.	73
10.	10.5	11.5	11	11	11	10.	127	35.	116	10.	105	35.	88
11.	10	10	10	9	9	11.	120	36.	130	11.	63	36.	133
12.	10	10	10	10	10.5	12.	83	37.	139	12.	117	37.	119
13.	9	8	9	9	9	13.	111	38.	119	13.	101	38.	121
14.	10	10	10	10	10	14.	95	39.	100	14.	70	39.	83
15.	9	9	9	9	9	15.	129	40.	87	15.	128	40.	113
16.	10	10	10	10	10	16.	137	41.	103	16.	109	41.	110
17.	11	10.5	11	11	10	17.	162	42.	122	17.	86	42.	86
18.	10	10	10	10	10	18.	124	43.	116	18.	99	43.	95
19.	10.5	10.5	10	10.5	10.5	19.	105	44.	92	19.	102	44.	112
20.	10.5	10.5	10.5	10	10	20.	86	45.	107	20.	112	45.	110
21.	10	10	10.5	10	10	21.	122	46.	126	21.	118	46.	116
22.	9.5	9.5	10	9.5	9.5	22.	101	47.	130	22.	107	47.	109
23.	10	10	10	10	10	23.	115	48.	118	23.	66	48.	109
24.	10	10	10	9.5	10	24.	108	49.	109	24.	72	49.	83
25.	10	10	10.5	9.5	10	25.	106	50.	105	25.	94	50.	78
Mean	10.63±.023 mm.					Mean	114±1.63			Mean	99.68±1.94		
Max.	11.5 mm.					Max.	162			Max.	166		
Min.	8.0 mm.					Min.	78			Min.	63		

Table 3.—Showing corolla measurements in mm., flowers per head and seed set per head, in Field No. 3, at Rocky Ford, 1927.

Corolla Measurements						Flowers Per Head				Seed Set Per Head			
Head No.	Tube length 1	2	3	Flower No. 4	5	Head No.	Flowers	Head No.	Flowers	Head No.	Seed	Head No.	Seed
1.	10	9.5	9.5	10	10	1.	110	26.	172	1.	72	26.	92
2.	11	10.5	10.5	10.5	10	2.	84	27.	125	2.	98	27.	89
3.	9.5	9	9	9	9.5	3.	160	28.	135	3.	68	28.	87
4.	10	10	10	10	9.5	4.	96	29.	140	4.	123	29.	70
5.	9.5	10	10	9.5	9.5	5.	97	30.	116	5.	69	30.	82
6.	9.5	9.5	10.5	10.5	10	6.	108	31.	84	6.	95	31.	83
7.	10	10	10	10	10	7.	148	32.	127	7.	82	32.	83
8.	10	10	10	10	10	8.	118	33.	121	8.	56	33.	140
9.	9.5	9.5	9.5	10	10	9.	83	34.	114	9.	92	34.	147
10.	9	9.5	10	10	10.5	10.	116	35.	115	10.	97	35.	95
11.	9	9	9	9	8	11.	94	36.	116	11.	101	36.	77
12.	10	10.5	10	10	10	12.	110	37.	123	12.	101	37.	66
13.	9	9.5	9	9	9	13.	122	38.	148	13.	83	38.	137
14.	10	10.5	11	10.5	10.5	14.	108	39.	104	14.	86	39.	81
15.	10.5	11	11	11	11	15.	125	40.	148	15.	92	40.	84
16.	9	9	9.5	9.5	9.5	16.	159	41.	115	16.	90	41.	92
17.	10	9	9.5	10	10	17.	133	42.	120	17.	146	42.	95
18.	9.5	9.5	9	9	8	18.	132	43.	86	18.	69	43.	73
19.	10	10	9.5	9.5	9.5	19.	118	44.	130	19.	97	44.	80
20.	10	10	10	10	10	20.	149	45.	106	20.	93	45.	93
21.	10	10	10	10	10	21.	119	46.	117	21.	71	46.	95
22.	9.5	10	10	9.5	10	22.	93	47.	124	22.	82	47.	93
23.	10	10	10	9.5	9.5	23.	90	48.	147	23.	115	48.	82
24.	9.5	9.5	9.5	9.5	9.5	24.	133	49.	112	24.	131	49.	92
25.	10	10	10	10	10	25.	102	50.	112	25.	45	50.	92
Mean	9.79±.033 mm.					Mean	119.28±1.93			Mean	91.04±2.02		
Max.	11 mm.					Max.	172			Max.	147		
Min.	8 mm.					Min.	83			Min.	45		

per head were secured from honeybee pollination and .0728 grams per head resulted from open-field pollination. Mr. Ward was at that time in charge of the Colorado Experiment Station farm at Rocky Ford and conveyed this information by letter.

The above mentioned yield of seed per head verifies the reports of large crops, since, according to Hollowell (9), 25 seeds per head assures a fair seed crop.

COMPETITION AMONG PLANTS FOR INSECT VISITANTS.—Determination was made to see if there was competition among plants for the attention of pollinators. Alfalfa and sweet clover are much in favor with honeybees and are very prevalent. A group of 102 heads of clover, which had bloomed and dried before alfalfa flowered, yielded 6411 seeds, an average of 62.84 seeds per head. Another group of 98 heads, flowering during the alfalfa bloom, yielded 7041 seeds, an average of 71.84 seeds per head. A third lot had been tagged for later study and were picked at harvesting time, but the seed was immature and not countable. From this, it appears that alfalfa was not a successful competitor for the attention of the pollinators of red clover in this instance. Sweet clover was not in advanced-blooming stage at the time. Honeybees do not secure pollen, in quantity, from alfalfa.

NIGHT POLLINATORS.—As previously mentioned, night pollinators were considered. Cages were removed from the plots for this study,

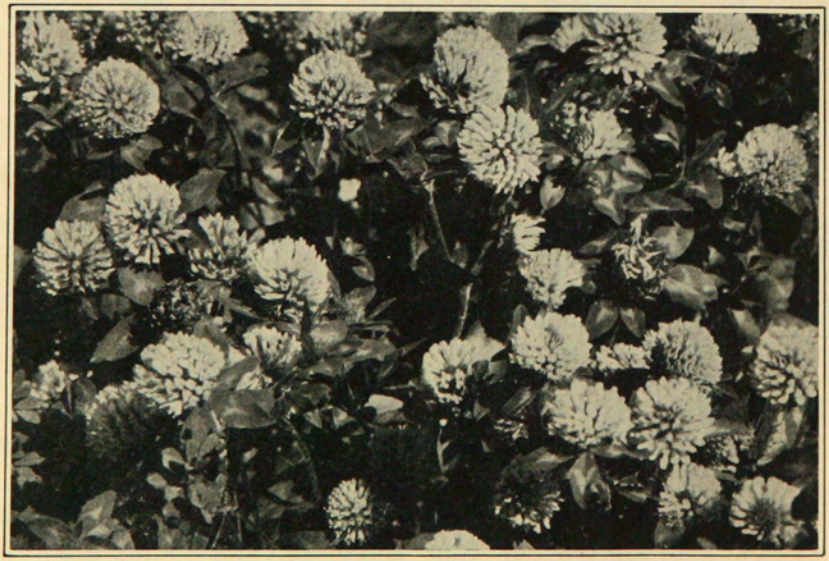

Figure 3.—Caged blossoms remain fresh longer than those in the open field.

Figure 4.—The corollas of pollinated flowers soon wither and die. These flowers are of the same age as those in Figure 3, in the same field and side by side.

just before daylight and just after dark. It was found that bumblebees are active at sunrise and after sunset. The long work hours of these insects may have allowed a slight error to creep into the calculations of seed set in the night-exposed plot. It was discovered that bumblebees work very early and only one occasion for such possible error was permitted. This observation does not agree with that of Gubin (8) who mentions that the honeybee starts its work earlier in the morning than the bumblebee. The observation by this author is questioned, in view of the fact that some bumblebees remain in the field over night and are ready to go to work as soon as the air warms up in the morning. All flowers in pollinating condition, when the cages were set in place, were picked. The cages were adjusted and 10 days allowed to elapse. By that time many blooms were in prime pollinating condition. The plots were then covered and uncovered alternately night and morning for 7 days and 7 nights. It was noted that in the daylight-exposed plot, after 2 days exposure, many of the heads showed drying corolla tubes. In the other cage, the tubes remained fresh for a much longer time. This observation was made also by Westgate and Coe (25).

After 7 days, the plots remained covered until enough heads were ripe and dry. These first dry heads were plucked from both cages and threshed. In picking, care was taken to select only the oldest-

appearing heads. From 109 heads, exposed in the daylight, 7371 seeds were taken, an average of 67.623 seeds per head. In 100 night-exposed heads, 99 seeds set, an average of .99 seeds per head. One-half of the seeds set in the night plot occurred in 5 heads, 75 having no seed at all. A bumblebee was busy on this plot for a few minutes prior to the first day's change of cages, which was just a few minutes late. Other investigators however, have found a few seeds set in cages where insects were excluded. Beal (3) mentions that during 8 years he covered clusters of flower heads of red clover and never failed to secure some seed.

The following summary of seed set under different conditions is evidence of the part played by the honeybee as a red-clover pollinator.

Table 4.—Showing seed set under different conditions.

Flower Treatment	Number of heads	Seed Set	Average Seed per head	Maximum Seed per head	Minimum Seed per head
Cage with bees	50	3077	61.54	133	1
Cage excluding pollinators	100	49	.49		
Open field, 1927	150	13984	93.23	166	36
Open field, 1930	200	13452	67.36	122	4
Night exposed	100	99	.99	23	0
Day exposed	109	7371	67.62	119	0
Alfalfa not a competitor	102	6411	62.84	122	4
Alfalfa in bloom	98	7041	71.84	115	19

To indicate the type of seed counted, samples were submitted to the Colorado Seed Laboratory and found to be 100 percent viable. These seed counts were made from first-crop clover and bear out the opinion of Hopkins (10) that red clover can and will set a good crop of seed. The writer has been unable to find research data to prove that the first crop does not produce seed.

RATIO OF FLOWERS TO SEED SET.—In determining the percentage of flowers setting seed, 50 heads in bloom were taken from each of three fields. Also 50 ripe heads were taken from the same three fields at the same time and the seed counted. No double or damaged heads were considered. While this method was inaccurate to some extent, no method suitable to this investigation was found by which flowers and seed could be accurately counted on the same head. The following table indicates the relationship of the number of flowers per head to the seed set per head, in three fields.

Table 5.—Comparison of seed set to flowers per head.

Field	Heads	Number of flowers	Seed set	Percentage setting seed
1	50	100.46±1.87	88.96±2.2	88.55
2	50	114.22±1.63	99.68±1.94	87.36
3	50	119.28±1.93	91.04±2.02	76.32

It was noted that Hopkins (10) counted the flowers on 23 average heads selected from different plants on the first crop and found them to have from 92 to 163 flowers, and an average of 112.7 flowers to the head.

THE FLOWER AT POLLINATING TIME.—In observing the condition of the flower at pollinating time, it was noted thruout these investigations that bees apparently prefer the flower in full flush bloom. Occasionally a bee would attend a flower before or after this time, but preference was given to those flowers as above mentioned. It was also observed that not all flowers on the same head come in full blossom at the same time. Most heads progress to pollinating condition, a few flowers at a time. The only time when all flowers on the same

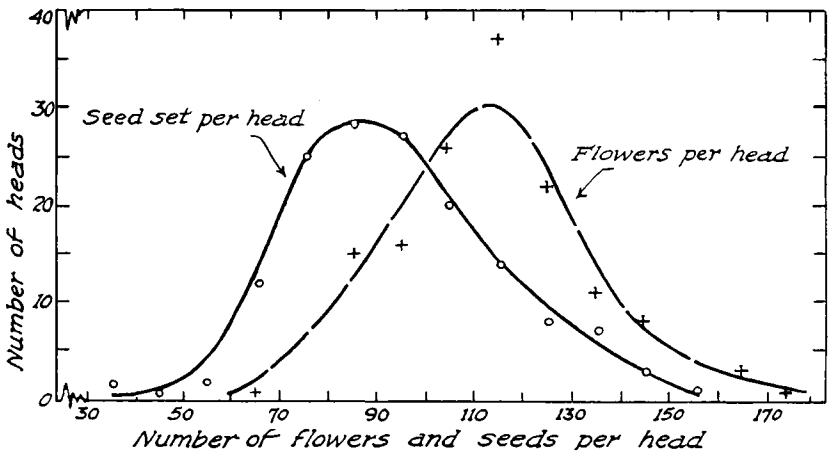

Figure 5.—Frequency curve showing comparison of distribution of flowers per head (+) and seed set per head (○), in 150 heads from three fields in 1927.

head were in bloom at once, was when cages covered the plants and excluded pollinating insects. This gave the head, at full bloom, the appearance of being much larger and more robust. Neither are all heads on the same plant in bloom at the same time. This sequence of flowering enhances the problem of selecting the time for cutting to secure an optimum seed crop.

While noting the condition of the flower, the presence or absence of nectar was remarked upon. Flowers were plucked from hundreds

of heads in many fields in Southern and Northern Colorado. Holding these flowers so that strong sunlight furnished good illumination, no nectar could be detected in the corolla tube. Efforts to squeeze nectar from the tube only resulted in a tiny moistness from broken plant tissues. An exceedingly delicate sweetness might be observed in sucking several tubes at once. Despite this apparent dearth, honeybees were observed inserting the proboscis down the tube, straining as tho to reach some nectar. The work of Parker (17) indicates that this is the method by which honeybees secure pollen from flowers of the type of red clover.

Corolla-tube measurements were made on 625 flowers from 125 heads, during two seasons. Some flowers were taken from the apex of the head, some from the side and some from the base, near the

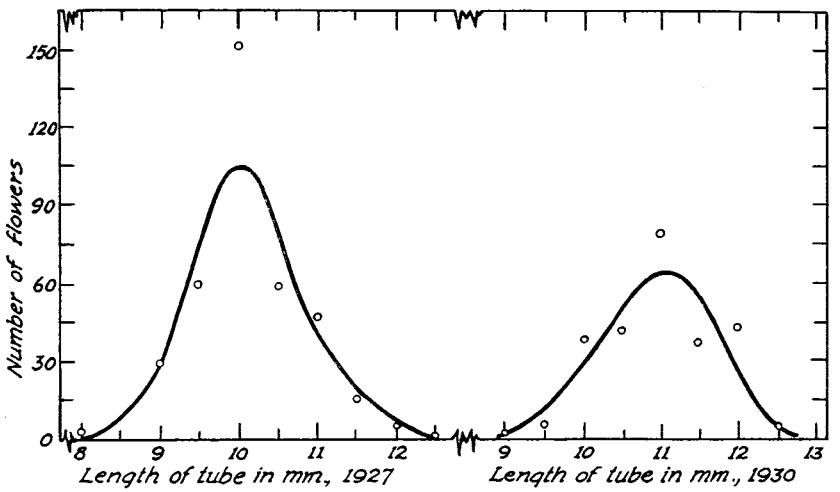

Figure 6.—Frequency curve of corolla-tube lengths in 374 flowers in 1927 and in 252 flowers in 1930.

Table 6.—Mean length of corolla tubes in millimeters, in five fields and two seasons.

Season	Field number	Number of flowers	Mean length
1927	1	125	10.6 ±.04
1927	2	125	10.63±.023
1927	3	124	9.79±.033
1930	4	125	10.91±.056
1930	5	127	11.1 ±.039
1927	1, 2 and 3	374	10.13±.024
1930	4 and 5	252	10.97±.031
1927 and 1930	1 to 5	626	10.47±.022

bracts. Selection depended on the position of the florets which were in prime pollinating condition. These measurements were made in the field without a microscope and extended from the base of the tube to the juncture of the vexillum and carina. Table 6 and Figures 6 and 7 show the results of this study.

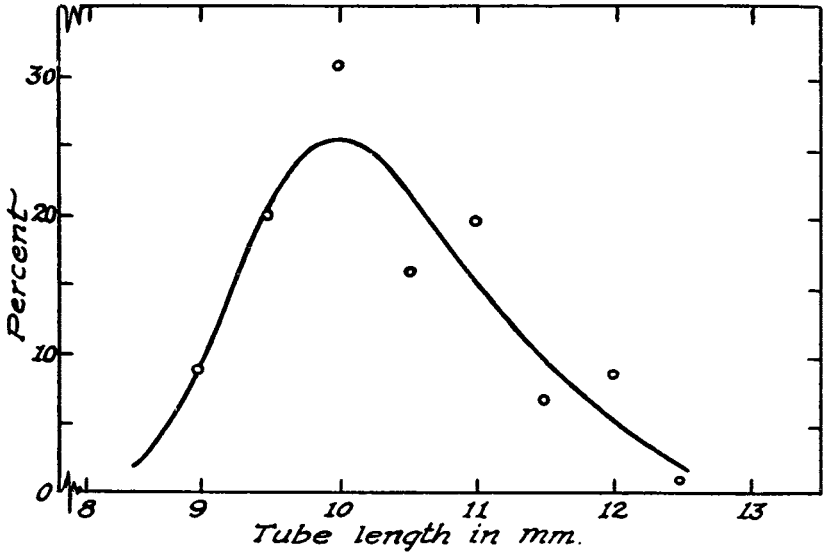

Figure 7.—Frequency curve showing percentage of corolla tubes occurring in certain lengths. Curve is based on data from 626 flowers, in five fields, during two seasons.

SUMMARY

1. Honeybees were found to be carrying red-clover pollen. A large percentage of the bees observed, were active pollinators of red clover. These insects are a major factor in pollination of this plant in Colorado, east of the mountains. Red clover seems to be a convenient and prolific source of pollen for honeybees in some Colorado localities.

2. Honeybees will carry nectar and pollen on the same fielding trip and both in considerable quantities.

3. Insects, capable of penetrating a 13-mesh screen wire, are a minor factor, if an agent at all, in the pollination of red clover at Fort Collins and Rocky Ford.

4. Night-flying insects are not instrumental in red-clover pollination at Fort Collins.

5. The length of the corolla tube apparently has no bearing on red-clover pollination by honeybees.

6. Alfalfa in bloom, does not withdraw the attention of honeybee pollinators from red clover.

7. First-cutting red clover sets a good crop of seed when conditions are such as to be inviting to honeybees.

8. There is a sequence of bloom among the flowers on the head and among the heads on the plant.

9. Corollas of unpollinated flowers remain in flush bloom much longer than those which have been attended by pollinators.

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