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THE OCCURRENCE OF DISEASES OF ADULT BEES

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INTRODUCTION.

THE DISEASES to which adult honeybees are subject have from time to time been discussed in the American beekeeping literature, but so far there has been no serious and widespread outbreak of any such trouble and not much work has been done in this country on the causes of these diseases. Because of the possibility of the introduction and establishment in the United States of another disease of adult bees which seems to be serious in its nature, it seems best at this time to publish the information at hand regarding the apparent absence of this disease in the United States. The purpose of this paper is to discuss the status of adult bee diseases, without reference to the details of work as to their causes. A list of citations is appended.

ISLE OF WIGHT DISEASE.

Isle of Wight disease is evidently a serious source of loss to beekeepers of the British Isles. It was first observed in 1904 in the Isle of Wight, hence the name, and in succeeding years it has spread with considerable rapidity to all parts of Great Britain. Because of the large losses from this disease reported by British beekeepers, it has been the subject of investigation by several workers for a number of years. It has been called acarine disease in England, from the order name (Acarina) of the mite which causes it.

Studies as to the cause.—At first a study was made of bacteria in the alimentary tract of the diseased bees, but this proved valueless in determining the cause. Later work indicated that the malady was due to the pathogenic action of *Nosema apis* (5, 6, 7, 8),¹ a proto-

¹ Reference is made by number (italic) to "Literature cited," p. 15

FIG. 1.—Mite associated with Isle of Wight disease: Male, dorsal view. (Hirst.)

FIG. 2.—Mite associated with Isle of Wight disease: Female, dorsal view. (Hirst.)

zoan parasite of the alimentary tract of adult honeybees, described by Zander (22, 23) in 1909. This protozoan has been found to be widely distributed in the United States and elsewhere throughout the world, without causing the serious conditions described for the Isle of Wight disease, and for this reason some doubt was cast on the results of the English workers in this field. Furthermore, the organism was found not to be present in all colonies suffering from Isle of Wight disease. Later Anderson and Rennie (1, 2) called these results in question, without, however, giving the cause of the disease, but *Nosema apis* came to be looked upon as a relatively harmless parasite. In December, 1920, Rennie and his associates announced that the Isle of Wight disease is caused by the parasitic mite *Tarsonemus woodi* Rennie, and the results of their work were published early in 1921 (9, 17, 18, 19, 21). Later the mite was placed in a new genus, *Acarapis* (figs. 1 and 2) by Hirst (10).

Search for Isle of Wight disease in the United States.—During the period when the Isle of Wight disease was attributed to *Nosema apis* there seemed to be no cause for alarm in the United States, but when this theory was disproven and another organism was given as the cause of the trouble, fears regarding the introduction of the disease were renewed. On the receipt of the published results of the work by Rennie (18), steps were at once taken to determine whether *Acarapis woodi* is present in the United States. Requests were sent out widely to beekeepers, asking that they send to the Bureau of Entomology samples of any adult bees which showed any unusual symptoms or any disease. During the summer of 1921 there were no reports from any part of the United States that indicated any serious diseases of adult bees. During the summer 200 samples were received, all of which were examined for all known causes of disease among adult bees. The examinations for the mites were made by J. B. Moorman, and A. P. Sturtevant examined the bees for *Nosema apis*. Certain samples were examined for arsenic, when there seemed reason to suspect poisoning as the cause of death, this work being done by the Bureau of Chemistry. Table 1, prepared by Mr. Sturtevant, gives the results of the examinations:

TABLE 1.—Results of examinations of adult bees.

State or country.	Counties.	Towns.	Negative.	<i>Nosema apis</i> .	Not examined for <i>Nosema</i> .	Arsenic.	Total.
Alabama.....	2	2	2				2
Arkansas.....	1	1			1		1
California.....	13	16	15	4+1?			20
Colorado.....	2	3	3	2			5
Connecticut.....	1	1	2	2			4
District of Columbia.....	1	1	2				2
Florida.....	2	2	1	1			2
Georgia.....	2	2	2				2

TABLE 1.—Results of examinations of adult bees—Continued.

State or country.	Counties.	Towns.	Negative.	Nosema apis.	Not examined for Nosema.	Arsenic.	Total.
Idaho.....	2	2	2	.....	1	.....	3
Illinois.....	6	7	5	2	1	.....	8
Indiana.....	6	6	5	2	.....	.....	7
Iowa.....	4	4	6	.....	.....	.....	6
Kansas.....	2	2	1	3	.....	.....	4
Kentucky.....	1	1	.....	1	.....	.....	1
Maryland.....	1	1	1	.....	.....	.....	1
Massachusetts.....	4	4	7	.....	.....	1	8
Michigan.....	6	6	5	3	.....	.....	8
Mississippi.....	1	1	1	.....	.....	.....	1
Missouri.....	2	2	2	.....	.....	.....	2
Montana.....	1	1	1	.....	.....	.....	1
Nevada.....	1	1	1	.....	.....	.....	1
New Jersey.....	7	7	5	1	.....	3	9
New Mexico.....	1	1	1	.....	.....	.....	1
New York.....	13	16	10	9	1	.....	20
North Carolina.....	4	5	7	1?	.....	.....	8
Ohio.....	8	8	8	2	.....	.....	10
Oklahoma.....	2	2	3	.....	.....	.....	3
Oregon.....	4	4	3	2	.....	.....	6
Pennsylvania.....	14	16	16	3	.....	.....	18
Rhode Island.....	1	1	1	.....	.....	.....	1
South Carolina.....	1	1	1	.....	.....	.....	1
South Dakota.....	1	1	1	.....	.....	.....	1
Tennessee.....	2	2	2	.....	.....	.....	2
Texas.....	3	3	2	1	.....	.....	3
Utah.....	2	3	4	.....	.....	.....	4
Virginia.....	4	4	4	.....	.....	.....	4
Washington.....	6	9	5	4	.....	.....	9
West Virginia.....	5	5	4	1	.....	.....	5
Wisconsin.....	5	5	4	1	.....	.....	5
Scotland.....	1	1	2	.....	.....	.....	2
Canada.....	1	1	.....	1	.....	.....	1
Total (41).....	146	161	147	45+2?	4	4	202

Since at the beginning of the examinations no specimens of *Acarapis woodi* had been seen by any of the workers in the United States, there existed some fear that they might in some way be overlooked. Through the courtesy of Prof. John Anderson, lecturer in beekeeping, University of Aberdeen, Scotland, two lots of bees suffering from the Isle of Wight disease were received and it was found that no difficulty exists in finding the mites when they are present. Not only are the mites themselves easily found on examining the tracheal tubes of the thorax, but the tracheal tubes are so discolored (as described by Rennie) as to make the detection of the infestation easy.

While negative results on only 200 samples do not prove the absence of the mite in the United States, the wide distribution of the samples received and the apparent absence of any serious adult bee disease indicate that the Isle of Wight disease does not exist within the limits of the United States. Statements regarding supposed cases of Isle of Wight disease have appeared in American bee journals from time to time, but there is nothing to support these diagnoses and such statements may be safely disregarded. It is desirable that further examinations be made as material is available.

Introduction through queen-mailing cages.—The shipments made by Prof. Anderson brought to light a fact of great importance. In the

first shipment all the bees were dead on arrival and no live mites were discovered. The bees had been selected from a colony that was being robbed, and the bees were apparently old and worn out before being sent. The second shipment consisted of a queenbee and attendants in a queen-mailing cage, all but two of the worker bees reaching Washington alive. The queen was not found to contain mites. Many of the accompanying living worker bees were found to contain living mites, showing conclusively that it is an easy matter to import the living mites to the United States. Living mites were found in worker bees after they had been dead for several days.

Means of preventing introduction.—If the reports of the great losses caused by the Isle of Wight disease in Great Britain are credited, and if it be assumed that the mite is not present in the United States, there is reason to look on the introduction of these mites as a dangerous possibility. Since the mites are so readily imported through the shipment of queenbees through the mails, it is a matter of some surprise that the disease is not found and universally distributed here. While some of the earliest importations of bees to the United States were made from England, such as the introduction to Massachusetts in the seventeenth century, the recent shipments of queens have been from Carniola, Cyprus, the Caucasus (chiefly through France), but especially from Italy. Because of the newness of the discovery regarding the cause of the Isle of Wight disease, the absence of any record of the occurrence of the mite in Italy or elsewhere on the continent of Europe² or Asia is without significance. There of course remains the possibility, but scarcely the probability, that the parasite is exceedingly local in its distribution, as stated by Rennie (18). This is supported by the belief of many British beekeepers that the disease was first limited to the Isle of Wight and then spread rapidly through the British Isles. It is now reported generally but not universally in those islands.

The fact that this mite belongs to or is related to the genus *Tarsonemus*, suggests that it may be at some stage of its life history a plant feeder, yet its specialized structure (4) (causing it to be put in a new genus by Hirst (10)) may be taken as evidence against this view. The fact that all stages of the mite have now been found in the tracheal tubes of the honeybee thorax would suggest its strictly parasitic habit.

The climatic conditions of the British Isles have been considered by some beekeepers as a contributing cause of the disease. While this is a possibility, unless the mite is associated with some species

² In the January, 1922, issue of *L'Apiculteur* (volume 66, No. 1, pp. 20-23) appears the announcement that the mite associated with the Isle of Wight disease has been found and determined by L. Berland, assistant in the Museum d'Histoire Naturelle (Paris), in bees sent through the editor of the above journal from the French Alps. The exact location is not recorded.

of plant which is limited in its distribution by these climatic conditions, this view is not probable. The fact that the honeybee so largely creates its own environment within the hive is against this view. Within the limits of the United States there is found such a diversity of climatic and floristic conditions that it would be impossible in the present state of knowledge regarding this disease to believe that the bees of this country are in no danger from this mite. While the work of Rennie and his associates bears evidence of thoroughness, there still remains the possibility that they are mistaken in attributing this disease to the mite. This possibility will be removed as work is done on this disease by other investigators. There is no question that the mite is present in colonies suffering from the disease.

Since at present it would be indicated that the Isle of Wight disease is not present in the United States, probably not in North America, the question of preventing its introduction is an immediate one. The ease with which the parasitic mites may be carried in queen-mailing cages, the most likely method of introduction, suggests the desirability of restricting or prohibiting the importation of queenbees. Restriction of importations of adult bees would entail considerable expense, since it would presumably be necessary to establish Government quarantine apiaries located near one or more of the usual places of entry.

Prohibition or restriction of importation of adult bees from the British Isles alone would be of little value, because of the ease with which queenbees and the accompanying workers could be sent to the Continent of Europe and reshipped to evade the law. It would also be folly to assume that the mite is restricted in its distribution to Great Britain until much more work is done on its distribution. Except during the period of the war, when importation of queens was almost impossible, a considerable number of queenbees have been sent to the United States every year for many years. Many of these queens are imported by beekeepers for their own use, on the presumption that they can get better stock in Italy than they can in the United States—an entirely erroneous belief. Many are also imported by specialist beekeepers who make a business of raising queenbees for sale. These men should be breeding better bees, instead of sending to Italy annually for unselected material for breeding work, and it is probable that a prohibition of importation would actually be desirable from the point of view of compelling better breeding methods. There is, so far as known, no race or strain of bees anywhere in the world superior to those that have already been introduced, and no obvious advantages come from the repeated importation of queenbees. If a prohibition on importation seems desirable for the present, and if at

some later time a better race of bees is found, provision might then be made for its importation under proper precautions. Prohibition rather than restriction through quarantine would seem preferable because of the high cost of such regulatory measures. At present there is no law which would seem to cover this case, and new legislation will be required to safeguard the beekeeping industry of the United States from this pest. It would be quite possible to provide by law for either restriction or prohibition, with the understanding that for the present only prohibition would be enforced. In view of the possibility that desirable races of bees may be found after further explorations have been made, especially in Africa, such a double provision would be desirable.

NOSEMA DISEASE.

In 1909 Zander (22, 23) described a protozoan parasite which is found in the alimentary tract of the adult honeybee and to which he attributed serious losses to beekeepers in continental Europe. Zander was evidently misled as to its seriousness. Following the announcement of his findings, investigators in all parts of the world began a search for this parasite, and it was soon found in several places in the United States, in Australia, and in various parts of Europe (3, 11, 12). From these various investigations information regarding the life history of the parasite was obtained, although some curious mistakes of observation were made and the literature is not in agreement regarding it.

As previously stated, some of the earlier work on the Isle of Wight disease in England indicated that it was caused by *Nosema apis*. This conclusion was reached by Fantham and Porter (5, 6), although their work contained errors regarding the life history and led to considerable confusion. Assuming that the results of this work were correct, and knowing that *Nosema apis* is a widely distributed parasite, those interested in bee-disease control naturally concluded either that the reports regarding Isle of Wight disease were grossly exaggerated or that the environmental conditions in the British Isles resulted in a more serious aspect of the disease than was observed elsewhere. Outside the British Isles there was no proof that *Nosema apis* causes great losses, although, perhaps misled by the work of Zander and Fantham and Porter, certain other investigators were led to attribute serious conditions to the organism. Those who knew the actual results of *Nosema apis* infection were inclined to question the results of the British investigators, and, as has been shown earlier, this work is now virtually disproven, in that the mite *Acarapis woodi* is now believed to be the cause of the Isle of Wight disease.

While there is a disease of adult bees caused by the pathogenic action of *Nosema apis*, the wide distribution of the parasite in the United States and the absence of any serious disease of adult bees

anywhere within this territory lead to the conclusion that the efforts to ascribe serious results to this organism are misleading. That a colony of bees may be weakened by heavy artificial infection of the organism is by no means proof that the organism under usual conditions of the apiary ever leads to the death of a colony. In fact, so far as can be determined from the present evidence, it is doubtful whether a colony of bees free to fly is seriously affected by this parasite. Petersen (13) observed many bees infected with *Nosema* spores, but observed no pathogenic symptoms.

The effects of food containing material which the bees are unable to digest (15), leading to the ordinary conditions of dysentery, and of various other environmental factors in permitting or encouraging the growth of the organism have not been adequately studied. Zander (22, 23) attributed an infectious dysentery to this organism, as distinguished from the ordinary dysentery with which beekeepers have long been familiar when the bees are wintered badly. It remains to be established whether conditions of ordinary dysentery are favorable to the growth of the organism, and whether it in turn causes certain additional conditions favorable to the death of the bees. Without wishing to underestimate the damage from *Nosema apis* alone, it is exceedingly doubtful whether it is the cause of a serious disease of bees.

Various names have been given to the disease caused by this organism, such as *Nosema* disease (a translation of Zander's name *Nosemaseuche*), *Microsporidiosis* (actually suggested as a substitute for the name *Isle of Wight* disease), *nosemosis*, *infectious dysentery*, and *Nosemakrankheit*.

Distribution by years.—During the years 1912, 1913, and 1921 special requests were sent out to beekeepers asking for samples of adult bees that appeared to be suffering from some disorder. This fact accounts for the larger numbers of samples received during these years. Table 2 shows the results of the examinations of samples received, so far as the presence of *Nosema apis* is concerned:

TABLE 2.—*Samples of Nosema disease, by years.*

Year.	<i>Nosema</i> present.	<i>Nosema</i> doubt- ful.	<i>Nosema</i> absent.	No diag- nosis for <i>Nosema</i> .	Total.
1910.....	0	0	6	13	19
1911.....	1	0	7	21	29
1912.....	35	0	49	16	100
1913.....	11	0	52	15	78
1914.....	0	0	14	9	23
1915.....	5	1	16	21	43
1916.....	6	2	31	4	43
1917.....	20	2	21	5	48
1918.....	8	1	20	1	30
1919.....	5	0	27	6	38
1920.....	9	0	22	1	32
1921.....	45	2	149	6	202
Total.....	145	5	414	118	685

Certain samples have been received in such bad condition as to make examination of any kind impossible. In other instances, samples were received in which the history did not indicate the necessity for laboratory examination. In recent years more care has been exercised in examining all samples of adult bees for the presence of *Nosema apis*, because of a desire to determine its distribution. The majority of the samples tabulated have been examined by A. P. Sturtevant, apicultural assistant. From 1905 to 1909, previous to the description of *Nosema apis*, a few samples of adult bees were received, but as at that time no examination was made for this organism, these samples, 14 in all, are not included.

Distribution by months.—Because of the possibility that *Nosema* disease is in some manner correlated with the activities of bees, and especially with the character of the food, it is desirable to present data as to the time of year at which the various samples have been received for examination. The dates used are those at which the samples reached the laboratory, which in a few cases might mean that they had been taken from the hives late the month preceding.

TABLE 3.—*Samples of Nosema disease, by months.*

Month.	Number of samples examined.	Number with <i>Nosema</i> .	Per cent of samples infected.	Month.	Number of samples examined.	Number with <i>Nosema</i> .	Per cent of samples infected.
January.....	11	0	0	August.....	64	8	12
February.....	21	1	5	September.....	37	2	5
March.....	37	7	19	October.....	23	0	0
April.....	60	14	23	November.....	16	3	19
May.....	146	39	27	December.....	17	8	47
June.....	141	33	23				
July.....	112	30	27	Total.....	685	145	.....
				Average.....			21

It would appear that there is more of this disease in early summer than at other times, but in some cases at least it is evident that the disease has started during the winter and has not been detected until the bees have become active. Since some samples were sent on request at particular times, the numbers for the several months can not be taken as too definite.

Geographical distribution.—Table 1 gives the distribution of 45 samples of *Nosema* disease received during the season of 1921.

The small number of samples of *Nosema* disease which have so far been diagnosed makes it impossible to draw definite conclusions regarding the geographical distribution of the disease. Samples have been received from 33 States and from three Canadian Provinces. There is also in the record a sample from Canada without information as to the Province from which it came.

TABLE 4.—The distribution of *Nosema* disease, by States.

California.....	9	Michigan.....	14	Tennessee.....	2
Colorado.....	2	Minnesota.....	2	Texas.....	1
Connecticut.....	6	Missouri.....	1	Utah.....	1
Florida.....	4	Nebraska.....	1	Vermont.....	1
Georgia.....	2	New Jersey.....	3	Virginia.....	1
Idaho.....	2	New York.....	21	Washington.....	9
Illinois.....	6	North Carolina.....	4	West Virginia.....	2
Indiana.....	3	Ohio.....	9	Wisconsin.....	5
Iowa.....	5	Oregon.....	6	Wyoming.....	1
Kansas.....	4	Pennsylvania.....	3	Total.....	145
Kentucky.....	2	Rhode Island.....	1		
Massachusetts.....	2	South Dakota.....	1		

The listing of these records by States fails to show the distribution by beekeeping regions. The clover region has furnished far more samples than any other. The alfalfa region shows comparatively little of the disease, while the sage and willow-herb regions of the West, in proportion to their sizes, show as much of the disease as does the clover region. The Southeastern States show few records.

The time of the year at which the samples have reached the laboratory from the various regions might throw some light on the character of the disease, as is the case with the records of European foulbrood. Because of the scant number of records, nothing definite can be learned from such an examination, but it seems probable that outbreaks of the disease may be expected more commonly in the Southern States during the winter and early spring. No samples have been received from this region during late summer. This suggests a relationship between wintering and *Nosema* disease.

Prevention of spread.—While it would seem possible for *Nosema apis* to remain virulent in honey for a short time, the danger of introducing *Nosema* disease to an apiary through honey as a carrier seems slight, especially in view of the fact that the organism is destroyed by the amount of heat to which honey is usually exposed in the process of bottling. The most probable means of distributing the organism to new locations would seem to be through the shipment of living bees. Obviously any precautions taken against the introduction of Isle of Wight disease by the restriction or prohibition of the importation of living adult bees would seem to be adequate to keep out any further introduction of *Nosema* disease, but the present wide distribution of *Nosema* disease, and especially its mild character, would seem to make unnecessary any quarantine measures against it alone.

ARSENICAL POISONING.

Most of the samples that have been received at the Bureau of Entomology have not been examined for the presence of arsenic, but in a few instances, where the history of the case suggested this as a possible cause of the trouble, examinations have been made through the courtesy of the Bureau of Chemistry. It is not the purpose of

the present discussion to take up the question of the losses incident to the poisoning of bees by ill-advised applications of poisonous materials in sprays used for the control of insect pests. There is reason to think that in some instances serious results have come from this use of arsenic. Aside from Isle of Wight disease and Nosema-disease, this is the only other cause of death of adult bees which at present can be determined by laboratory methods.

NEGATIVE RESULTS.

The most regrettable fact about the data so far obtained on the diseases of adult bees is that so many of the samples have given negative results. This is due partly to the fact that certain diseases of adult bees exist for which the causes have not been determined. The serious nature of the diseases of the brood of bees has made it necessary that more attention be given to these, and while the causes of the three diseases of the brood have been learned, little good work has as yet been done on the diseases of adult bees.

Attention should be called to the fact that many samples have been received which could not be diagnosed by laboratory methods. The greatest abnormal death of colonies of bees is doubtless due to poor wintering or to losses indirectly to be attributed to this cause. The condition known to beekeepers as dysentery is caused by an accumulation of feces in the alimentary tract, due to a poor quality of food and to a rapid accumulation due to excessive heat generation made necessary by improper care in winter. These conditions have been fully discussed in the publications of the United States Department of Agriculture on wintering. In some instances it is possible to surmise that the samples of dead bees have been taken from colonies that have died because the beekeeper did not take proper care of his bees in winter, but proof from laboratory diagnosis would be difficult or impossible. When bees are received in early spring which show a large volume of feces, this diagnosis is rather definite.

A large number of cases possibly arise from the death of colonies observed after brood-rearing has begun in the spring, and this the beekeeper usually calls spring dwindling rather than winter loss. It has been shown that the death of bees after brood-rearing is under way in the spring is also a result of poor wintering, and should properly be so diagnosed. There is no other known cause of the condition known as spring dwindling. While laboratory proof of such a condition is difficult, the well-known deficiency in winter protection, so prevalent throughout the United States, suggests this as a major cause of the death of bees submitted for examination. This has been recognized elsewhere than in the United States, for in the work on the Isle of Wight disease in England it was found

desirable to eliminate bees dying from exhaustion, and Mrs. Pixell-Goodrich (15) has worked out methods for the determination of death from old age. It is out of the question to submit all the samples received by the Bureau of Entomology to the tests which she has described, but there can be no question that death from quite natural causes induced by poor care is often mistaken by beekeepers for the work of some disease.

Even though we eliminate the cases where there is reason to suspect poor care as the cause of death of adult bees, there still remain cases where evidence exists that death is due to some disease which can not be diagnosed in the laboratory at present. Cases which answer to the usual description of the so-called bee paralysis can not be diagnosed in the laboratory because there is still doubt as to the cause or causes of the trouble. According to Turesson (20) this disease is due to the molds which bees sometimes get in their food under unsatisfactory conditions in the hive, such as those of damp hives in winter. Whether there is more than one condition which is put under this name by beekeepers is still a matter of doubt (14). Other names have been given by beekeepers to abnormal death of adult bees, among which may be mentioned May disease (rarely used in the United States) and disappearing disease. The multiplication of names without adequate descriptions of symptoms or some other means of differentiating the disease has nothing to commend it, and beekeepers will do well to avoid the making of new and confusing names for adult bee diseases.

A serious difficulty arises from the fact that the symptoms observed for almost all the conditions which cause the abnormal death of adult bees are much alike. Even for Nosema disease, the cause of which is known, there is no definite description of symptoms, and this is likewise to a considerable degree true of the Isle of Wight disease. Abnormal bees behave much alike, whatever the cause of the abnormality, and the descriptions of characteristic symptoms for the several diseases is exceedingly difficult. Symptoms of adult bee diseases can not be described from the appearance of the dead bees, as is the case with the brood diseases.

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