Issued September 9, 1912.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY.—BULLETIN 152.
A. D. MELVIN, CHIEF OF BUREAU.

STUDIES ON THE BIOLOGY OF THE TEXAS-FEVER TICK.

(SUPPLEMENTARY REPORT.)

BY

H. W. GRAYBILL, D. V. M.,
Assistant Zoologist, Zoological Division,

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Agent in Tick Eradication, Bureau of Animal Industry.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY,
Washington, D. C., April 25, 1912.

SIR: In Bulletin 130 of this bureau there were reported the results of one year's investigations of the biology of the Texas-fever tick which were carried on during 1907 and 1908 at Auburn, Ala., by cooperation between the Alabama Polytechnic Institute and this bureau. The work was continued for another year, and I have the honor to transmit herewith a supplementary report by Dr. H. W. Graybill and Mr. W. M. Lewallen, giving the results of the second year's experiments (1908–9). As this information has a bearing on the cooperative work now being carried on by the bureau and the authorities of certain States for the eradication of the cattle tick, I recommend its publication as a bulletin of this bureau.

Respectfully,

A. D. MELVIN,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

STUDIES ON THE BIOLOGY OF THE TEXAS-FEVER TICK.

(SUPPLEMENTARY REPORT.)

INTRODUCTION.

During 1907–8 the Zoological Division of the Bureau of Animal Industry conducted a year's experiments on the life history of the Texas-fever tick at Auburn, Ala., in cooperation with the veterinary department of the Alabama Polytechnic Institute. The results obtained during the course of those investigations have been published in Bulletin 130 of the Bureau of Animal Industry. The work was continued for another year (1908–9) along the same but somewhat less extensive lines. Mr. W. M. Lewallen, who assisted in the first year's work, had charge of the experiments during the second year.

The second year's work was undertaken for the purpose of obtaining additional data on the nonparasitic periods in the life history of the tick, and to determine what variations might take place in the duration of these as a result of yearly variations in weather conditions.

METHODS OF STUDY.

The methods of study employed were the same as those used the first year. The indoor experiments were conducted by the use of incubation tubes, and these were checked by outdoor experiments conducted in field plots representing natural conditions. The incubation tubes used were the vertical type provided with a glass tube inserted into the bottom for the purpose of supplying the sand with moisture, shown in figure 1, Bulletin 130, Bureau of Animal Industry. The field plots were the same as those used in the first year's work (fig. 3, Bulletin 130), being 2 feet square. They were protected from the intrusion of small animals by means of a wire-netting fence.

In the indoor experiments the ticks were handled the same as during the first year. Four engorged ticks were collected at the beginning of each month, and each was placed in a dish by itself, where it remained until oviposition was completed. At the end of every 24 hours the eggs were removed from each tick, counted, and placed in an incubation tube marked with the number assigned the tick and the date the eggs were removed. The dates when the eggs in each tube began and completed hatching, and when the first and last larvæ

died, were recorded, and finally the per cent of eggs that hatched was determined. The indoor experiments were conducted in an unheated room, the windows of which were constantly open.

In the outdoor experiments two sets of plots were run, one located in a place shaded a part of the day and the other in the sun. In each plot 10 engorged females were placed.

PREOVIPOSITION PERIOD.

The minimum preoviposition period noted was 2 days, which occurred in the case of ticks collected in August. Ticks collected in August the first year had a minimum period of 2 days, but the minimum for the year (1 day) was observed in the case of a tick collected in April. The maximum period (29 days) was exhibited by ticks collected December 2, and the maximum for the first year (98 days) was observed in the case of a tick collected November 30.

From the table (last column) it will be noted that the average preoviposition periods increase month by month from the minimum to the maximum, and then decrease again to the minimum. A similar increase and decrease were also shown in the case of averages for the first year's experiments in the horizontal tubes, but in the case of the ticks used for the vertical-tube experiments the averages for April and June were greater than for March.

Preoviposition period—Range and average length of periods.

Date ticks were collected.	Number of ticks.	Range of preoviposition periods.	Average of preoviposition periods.	Date ticks were collected.	Number of ticks.	Range of preoviposition periods.	Average of preoviposition periods.
1908.		*Days.*	*Days.*	1909.		*Days.*	*Days.*
August 5	4	2 to 4	3	January 1	4	22 to 24	23
September 1	4	3 to 5	4	February 4	4	18 to 20	19.3
October 1	4	5 to 11	7.8	March 1	4	9 to 16	11.8
November 2	4	7 to 9	8.3	April 2	4	9 to 10	9.8
December 2	4	17 to 29	25.5	July 2	4	3	3

OVIPOSITION PERIOD.

The longest oviposition period noted was 82 days, observed in the case of a tick which began ovipositing in January. A tick in the first year's experiments which began to lay eggs in January had an oviposition period of 91 days, but the longest period was exhibited by a tick which began ovipositing in November and continued to lay eggs for 152 days. The second year the shortest period (7 days), as well as the longest, occurred in January. The tick giving this period, however, deposited only 305 eggs, an exceptionally small number. The shortest period the first year was 3 days, and this occurred in June. The average oviposition periods for the first year increased month by month from a minimum in June to a maximum in November, and

gradually decreased again in the succeeding months. During the second year the same tendency was shown, the periods increasing from a minimum in August to a maximum in November, and then, following a sudden decrease for December, there was an increase for January and February, after which the decrease was regular for the remaining months.

Oviposition period—Range and average length of periods.

Month oviposition began.	Number of ticks.	Range of oviposition periods.	Average of oviposition periods.	Month oviposition began.	Number of ticks.	Range of oviposition periods.	Average of oviposition periods.
1908.		*Days.*	*Days.*	1909.		*Days.*	*Days.*
August	4	13 to 15	14.3	February	4	37 to 59	46.8
September	4	9 to 18	14.8	March	4	22 to 42	33.3
October	4	13 to 35	25.3	April	4	26 to 32	29
November	4	56 to 63	59.5	May	4	19 to 27	23.8
December	4	30 to 42	34.5	June	4	11 to 19	15.8
1909.				July	4	12 to 17	14.8
January	4	7 to 82	45.8				

INCUBATION PERIOD.

The range of the incubation periods of the lots of eggs laid by each tick is given in the table in the Appendix. The range of the period for the second year was 18 to 176 days, as compared with 19 to 188 days for the first year. In the table below only the periods from the time the eggs were deposited until the first eggs hatched in each lot have been used, and these are referred to for convenience as the minimum incubation periods. The periods to the hatching of the last eggs in each lot have been included in the table in the Appendix. The longest minimum incubation period for both the first and the second year occurred in the case of lots of eggs deposited during the month of October, being 173 days for the second year and 180 days for the first year. The shortest period for the second year was 18 days and was observed in the case of lots of eggs deposited during the month of June, while the lots deposited during the same month of the first year gave a minimum period of 22 days. The shortest period for the first year (19 days) was furnished by lots of eggs deposited during the months of July and August.

By comparing the averages in the table below it will be observed that they increase from August to October and decrease for the remaining months, except in the case of the average for July, which shows a slight increase. In case of the averages for the first year it is noted that they increase for the months of August to October and decrease for the remaining months without interruption.

Minimum incubation period—Range and average length of periods.

Month eggs deposited.	Number of lots.	Range of periods.	Average of periods.	Month eggs deposited.	Number of lots.	Range of periods.	Average of periods.
1908.		*Days.*	*Days.*	1909.		*Days.*	*Days.*
August	52	20 to 30	23.1	February	48	82 to 107	95.5
September	49	32 to 70	44.8	March	170	58 to 90	71.5
October	49	141 to 173	158.7	April	141	38 to 65	47.5
November	66	151 to 171	157.5	May	90	26 to 39	30.6
December	21	139 to 158	150.3	June	47	18 to 26	22.9
				July	51	22 to 27	24.5
1909.							
January	70	103 to 141	121.6				

HATCHING PERIOD.

The maximum hatching period for the second year was 52 days and for the first year 49 days, and in the case of both years this period belonged to a tick whose eggs began to hatch during the month of October. The shortest hatching period for the second year was 6 days and occurred in the case of a tick whose eggs began to hatch in May, while for the first year the minimum period for the same month was 9 days. The shortest period during the first year (4 days) fell to the month of July. It is noted by referring to the averages in the table below that those for October and February are the same, and for the remaining months, with the exception of the break shown by May, there is a decrease, month by month, of the averages. In the first year's work the averages increased from that for July to the maximum, which is for the month of October, and decreased for the remaining months, except for a slight increase for the month of June.

Hatching period—Range and average length of periods.

Month hatching began.	Number of ticks.	Range of hatching periods.	Average of hatching periods.	Month hatching began.	Number of ticks.	Range of hatching periods.	Average of hatching periods.
1908.		*Days.*	*Days.*	1909.		*Days.*	*Days.*
August	4	17 to 27	21.5	March	2	33 to 46	39.5
October	4	47 to 52	50	April	4	18 to 21	19.3
				May	20	6 to 21	13.8
1909.				June	4	12 to 18	16
February	1	50	50	July	8	11 to 21	14.5

LONGEVITY PERIOD.

The longest and shortest longevity periods obtained for the lots of larvæ belonging to each tick are given in the table in the Appendix. The time to the death of the first larvæ in each lot is referred to in the table below as the minimum longevity period and that to the death of the last larvæ as the maximum longevity period. The longest maximum longevity period for the second year was 249 days, as compared with 234 days for the first year, and both

occurred in the case of lots of eggs which began to hatch during the month of October. In referring to the averages it will be noted that there is no regular increase and decrease to and from the maximum, and the same was noted in the case of the first year's experiments. This is no doubt due to the fact that temperature, while it plays some part, is not a controlling factor in the longevity of larvæ as it is in the case of the preoviposition, oviposition, hatching, and incubation periods. The range of the averages for the months of August to November of the second year is 104.5 to 213.7 days, whereas the range for the same months of the first year is 56.2 to 167.4 days. The range of the averages for the rest of the months of the second year is 63.3 to 77.6 days, as compared with a range of 38.6 to 73.2 for the remaining months of the first year.

Longevity period.—Range of maximum and minimum longevity and average of maximum longevity.

Month lots began to hatch.	Number of lots.	Range of minimum longevity periods.	Range of maximum longevity periods.	Average of maximum longevity periods.	Month lots began to hatch.	Number of lots.	Range of minimum longevity periods.	Range of maximum longevity periods.	Average of maximum longevity periods.
1908.		*Days.*	*Days.*	*Days.*	1909.		*Days.*	*Days.*	*Days.*
August.....	6	16 to 36	99 to 192	121.8	April.....	72	6 to 60	31 to 110	75.3
September..	46	6 to 62	50 to 218	104.5	May.....	355	8 to 87	14 to 119	77.6
October.....	31	13 to 155	80 to 249	213.7	June.....	180	7 to 85	25 to 139	66.1
November..	18	51 to 146	58 to 223	149.9	July.....	56	9 to 48	9 to 106	63.3
					August.....	42	7 to 47	31 to 118	64.6
1909.									
March.....	30	10 to 42	10 to 112	71.6					

ENTIRE TIME OF NONPARASITIC DEVELOPMENT.

The entire time for each individual tick and its progeny, i. e., the time from dropping to the death of all the larvæ, is given in the table in the Appendix. The longest entire time during the second year (297 days) was obtained in the case of ticks collected September 1, while the longest period for the first year (288 days) occurred in the case of ticks collected October 1. The shortest period for the second year was 96 days and for the first year 79 days, and both occurred in the case of ticks collected the first part of June. The averages for the first year increase month by month from June to a maximum for October, and then decrease for the remaining months, except that the averages for February and March are the same. The averages for the second year, given in the last column of the table below, do not increase to and decrease from the maximum without deviations, as do those for the first year.

Entire time of nonparasitic development.

Date engorged females were collected.	Number of engorged females.	Range of entire-time periods.	Average of periods.	Date engorged females were collected.	Number of engorged females.	Range of entire-time periods.	Average of periods.
1908.		*Days.*	*Days.*	1909.		*Days.*	*Days.*
August 5	4	143 to 254	206.5	January 1	4	202 to 253	235
September 1	4	258 to 297	280	February 4	4	204 to 230	218.5
October 1	3	271 to 280	279.3	March 1	4	185 to 207	198.3
November 2	4	274 to 288	282	April 2	4	139 to 164	154
December 2	4	257 to 268	264.8	May 1 (?)	4	140 to 185	156.5
				June 2 (?)	4	96 to 127	117
				July 2	4	110 to 149	129.5

NUMBER OF EGGS LAID AND PERCENTAGE HATCHED.

During the second year the minimum number of eggs laid by a tick was 305 and the maximum 4,492. The average number of eggs laid by the various lots of ticks ranged from 1,885 to 4,262. The lowest percentage of eggs hatched was 3 per cent and the highest 98 per cent. The percentage of eggs hatched in the case of ticks collected during December, January, and February ranged from 3 to 60 per cent. For the first year the minimum number of eggs laid was 357 and the maximum number was 5,105, and the averages ranged from 1,811 to 4,089. The percentage of eggs hatched ranged from 0 to 98 per cent.

Egg laying and hatching—Total and average number of eggs laid and per cent hatched.

Date collected.	Number of ticks.	Number of eggs deposited.	Average number of eggs.	Per cent of eggs hatched.	Date collected.	Number of ticks.	Number of eggs deposited.	Average number of eggs.	Per cent of eggs hatched.
1908.					1909.				
August 5	4	3,962 to 4,492	4,262	48 to 97	January 1	4	305 to 3,723	2,615	3 to 60
September 1	4	2,797 to 3,654	3,252	92 to 98	February 4	4	1,993 to 2,970	2,568	11 to 41
October 1	4	1,588 to 3,848	2,768	9 to 61	March 1	4	1,380 to 3,361	2,352	61 to 93
November 2	4	2,215 to 3,329	2,975	52 to 71	April 2	4	1,741 to 3,065	2,476	86 to 95
December 2	4	1,496 to 2,201	1,885	11 to 27	May 1[1]	4	3,181 to 4,178	3,674	69 to 93
					June 2[2]	4	1,640 to 3,003	2,180	60 to 97
					July 2	4	2,214 to 3,710	2,948	96 to 98

[1] Ticks were collected May 1 and 2.

[2] Ticks were collected June 2, 3, 4, and 5.

COMPARISON OF RESULTS OF INDOOR AND OUTDOOR EXPERIMENTS.

In the next table the dates when the first eggs hatched and when all the larvæ were dead in each month's experiments, indoors and outdoors, are given for purposes of comparison. These dates are of much practical importance in eradication work when rotation methods are employed, since the dates when the first eggs hatched are those on which ticky cattle placed on tick-free land on dates corresponding to those on which the experiments were begun will be in danger of reinfestation, and the dates on which all larvæ were dead are the

dates on which pastures from which all animals have been removed will be free of ticks.

Comparison of records of vertical tubes and field plots, Auburn, Ala., 1908–9.

Vertical tubes.			Field plots.		
Date females were collected.	Date first eggs hatched.	Date all larvæ were dead.	Date females were collected.	Date first eggs hatched.	Date all larvæ were dead.
1908.			1908.		
August 5	Aug. 30	Apr. 16	August 5–6	Aug. 31	Apr. 3
September 1	Oct. 7	June 25	September 1	Nov. 23	May 22
October 1	Feb. 25	July 8	October 1	Apr. 19	June 23
November 2	Apr. 22	Aug. 17	November 2	May 10	Do.
December 2	May 11	Aug. 27			
1909.			1909.		
January 1	May 19	Sept. 11	January 1	May 21	July 30
February 4	May 21	Sept. 22	February 1–4	May 20	Aug. 6
March 1	May 24	Sept. 24	March 1–3	...do	Aug. 25
April 2	May 28	Sept. 13	April 2	May 26	Sept. 11
May 1–2	June 10	Nov. 2	May 1–2	June 12	Do.
June 2–5	July 2	Oct. 7	June 2–5	June 28	Oct. 2
July 2	July 28	Nov. 28	July 1–2	July 26	Nov. 13

In comparing the length of time required for the first eggs to hatch in the indoor and outdoor experiments it was found that for all the months except March, April, June, and July the time was longer in the outdoor than in the indoor experiments, the differences ranging from 1 to 53 days, and for the above-mentioned months the time was shorter, the differences ranging from 1 to 4 days. The longer time obtained in the majority of the outdoor experiments may be due in part to unavoidable errors in observation because of the fact that it is frequently difficult to determine with certainty when the first eggs hatch, since they are scattered and some may be hidden from view. In the first year's experiments practically the same results were obtained. For two of the eight months for which comparisons could be made the time was the same in the indoor and outdoor experiments, and for the remaining months the time was longer in the outdoor experiments, the differences ranging from 1 to 22 days.

In view of the fact that in the two years' experiments the time to the hatching of the first eggs was longer in the outdoor experiments than in the corresponding indoor experiments in all except four instances, in which cases the differences were comparatively small, ranging from 1 to 4 days, it seems safe to assume that indoor experiments, if the temperature is maintained near that on the outside, will be safe to follow in practical work, provided a reasonable margin of safety be allowed to cover slight variations that might occur in the direction of a shorter time for hatching.

In the second year's work, for all months the time required for all the larvæ to die was longer in the indoor than in the outdoor experiments, the differences ranging from 2 to 55 days, and the average

difference being 28 days. In the first year's experiments similar results were obtained; in all but one case the periods were longer in the indoor than the outdoor experiments, the differences ranging from 5 to 42 days, the average difference being 21 days. It therefore appears that the time obtained indoors, with incubation tubes of the type employed, as a rule will be three to four weeks longer than that occurring under natural conditions. This is what would be expected, since ticks in tubes are not exposed to the wind, and when kept indoors are not subjected to the sun, in consequence of which they will not suffer the loss of body fluids and nourishment that ticks living in the open will. In addition to this, it is likely that the humidity in the tubes as a rule is higher than that of the outside air, which would tend to prolong longevity of the larvæ. It is believed that in using tubes such as were employed, the supply of moisture should not be excessive, the sand simply being kept moist. Unless this is done it is likely that the life of the larvæ may be prolonged far beyond that occurring under natural conditions. Unduly long periods for the death of all larvæ, obtained by using incubation tubes, are safe but uneconomical, requiring the farmer to forego the use of his land longer than is necessary. It is important that the periods be ample, but it is likewise important that they be no more than this, since rotation methods are inconvenient and expensive at best in the majority of instances.

In comparing the time required for all the larvæ to die for corresponding months in the indoor experiments for the two years it was found that for all but one month the time was longer the second year, the differences ranging from 3 to 45 days. The average difference was 25 days. A similar comparison of the outdoor experiments for the two years showed that in every instance the time was longer the second year, the differences ranging from 2 to 36 days. The average difference was 17 days.

APPENDIX.

Individual records of ticks used in experiments.

Number of tick.	Date collected.	Number of eggs deposited.	Preoviposition period.	Oviposition period.	Hatching period.	Incubation period.	Minimum longevity.	Maximum longevity.	Entire time.	Per cent hatched.
	1908.		*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	
1	Aug. 5	4,492	3	15	27	20 to 36	15	116	143	48
2	do	3,962	4	13	17	20 to 30	12	218	254	97
3	do	4,489	3	15	24	21 to 34	17	141	182	61
4	do	4,104	2	14	18	21 to 30	6	207	247	60
5	Sept. 1	3,654	3	16	52	32 to 73	58	249	286	98
6	do	3,604	4	18	51	36 to 75	15	237	279	92
7	do	2,951	4	9	47	31 to 71	21	222	258	93
8	do	2,797	5	16	50	34 to 70	13	249	297	92
9	Oct. 1	1,588	11	13						
10	do	3,848	5	35	50	141 to 176	10	100	280	19
11	do	2,730	7	20	33	151 to 174	10	87	271	9
12	do	2,906	8	33	46	146 to 174	7	112	278	61
13	Nov. 2	3,187	7	63	18	151 to 170	11	107	285	52
14	do	3,329	9	56	19	152 to 168	6	98	274	57
15	do	3,167	8	58	19	151 to 170	14	110	281	59
16	do	2,215	9	61	21	143 to 169	18	106	288	71
17	Dec. 2	1,858	28	31	9	114 to 138	18	100	268	27
18	do	1,985	28	35	18	103 to 142	8	97	266	17
19	do	2,201	17	42	16	116 to 144	19	100	268	15
20	do	1,496	29	30	9	115 to 139	8	87	257	11
	1909.									
21	Jan. 1	3,723	24	82	21	61 to 119	16	104	243	60
22	do	3,460	24	48	18	73 to 120	16	113	253	18
23	do	2,970	22	46	16	94 to 121	21	103	242	17
24	do	305	22	7	6	111 to 117	49	64	202	3
25	Feb. 4	2,601	19	49	17	53 to 87	17	98	204	33
26	do	2,970	18	42	17	68 to 97	21	114	225	36
27	do	2,706	20	59	14	49 to 87	7	111	230	41
28	do	1,993	20	37	12	70 to 90	28	106	215	11
29	Mar. 1	2,994	9	41	15	45 to 81	25	116	205	79
30	do	1,674	10	28	8	57 to 84	14	107	196	61
31	do	3,361	12	42	14	44 to 77	25	97	185	93
32	do	1,380	16	22	8	55 to 77	25	119	207	62
33	Apr. 2	2,607	9	26	17	36 to 49	20	106	164	94
34	do	3,065	10	32	13	39 to 50	23	95	154	86
35	do	1,741	10	27	14	39 to 51	15	101	159	94
36	do	2,491	10	31	14	35 to 48	11	81	139	95
37	May 1[1]	4,178	.....	27	18	26 to 39	19	118	158	93
38	do	4,040	.....	25	17	27 to 37	17	96	140	73
39	do	3,181	.....	24	17	28 to 36	25	100	143	85
40	do	3,296	.....	19	12	27 to 41	14	139	185	69
41	June 2[2]	2,311	.....	19	13	18 to 27	18	80	114	97
42	do	3,003	.....	11	13	21 to 27	20	95	127	84
43	do	1,765	.....	15	13	22 to 29	20	62	96	60
44	do	1,640	.....	18	11	21 to 27	9	84	117	89
45	July 2	3,452	3	15	16	24 to 27	12	118	149	98
46	do	3,710	3	17	21	22 to 27	13	94	125	98
47	do	2,214	3	12	15	23 to 29	20	81	110	96
48	do	2,416	3	15	14	23 to 28	7	106	134	98

[1] Ticks were collected May 1 and 2.

[2] Ticks were collected June 2, 3, 4, and 5.