LEAFHOPPER RESPONSE TO COLORED LIGHTS.

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Many persons have observed leafhoppers flying about an electric light at night and collectors, especially, have taken many species there. With the passing of the old electric arc light and the universal use of incandescent bulbs, insect attraction to light has not been so great. Almost everyone can recall the swarms of insects around an arc light. It is true that the present street lights and other lights attract insects, but without doubt much of the ultra is lost in the modern lights and hence much of their insect attractiveness.

The writer first became interested in the response of leafhoppers to colored lights in 1927 while testing the response of corn borer moths to colored lights under outdoor conditions. The apparatus was inside a screened insectary, so the leafhoppers had to pass through two screens of 12-mesh in order to reach the lights. At times the leafhoppers were so numerous that they proved a nuisance while making observations.

The 1927 data are recorded in Tables I and II. All of these data were incidental to the regular corn borer light experiments so that the set up and procedure were identical with that of the corn borer. The apparatus was set up three feet from the ground, which was the average height of the corn at the peak of moth flight.

The leafhopper apparatus for 1930 and 1931 was the same as that used for the corn borer except that all the screen was removed except from around the bulbs. The data presented below are the result of two summers' work and it is hoped that they will give additional weight to some of the writer's former work on the response of the European corn borer to colored lights.

METHODS.

The apparatus consisted of a wooden framework divided into six compartments so arranged that the leafhoppers could enter from two sides and the top. Four heights were tried

TABLE I.

SHOWING THE RESPONSE OF LEAFHOPPERS TO COLORED BULBS. 1927.

COLOR OF BULB	DATES AND NUMBER OF LEAFHOPPERS RESPONDING TO LIGHTS				
	July 14	July 18	July 26	July 31	Totals
Blue	0	0	1	0	1
Green	26	82	269	17	394
Ivory	58	216	480*	67	821
Buff	18	41	34	11	104
Brown	3	95	27	14	139
Red	0	14	1	1	16
Total	105	448	812	110	1475
Temp. 9:00 P. M.	62	76	73	69	
Temp. 10:00 P. M.	62	78	70	66	
Humidity	70.5		58	45	

*The leafhoppers came so fast on July 26 that only 480 were counted, as the writer and Dr. J. P. Sleesman had to stop because they got into our eyes and mouths. There were at least 150-200 more that were not counted.

TABLE II.

SHOWING THE RESPONSE OF LEAFHOPPERS TO COLORED BULBS BY FIFTEEN-MINUTE INTERVALS. 1927.

TIME	9:00	9:15	9:30	9:45	10:00	10:15	10:30	10:45	11:15	11:45	TOTALS
Blue	0	0	1	0	0	0	0				1
Green	8	7	11	15	17	18	14				90
Ivory	32	30	49	57	67	66	66				367
Buff	9	9	10	14	14	14	15				85
Brown	6	6	10	12	11	12	9				66
Red	2	1	1	1	1	1	2				9
Total	57	53	82	99	110	111	106				618
Blue			2	2	1		1	1	0	0	7
Green			11	18	37		36	76	82	61	321
Ivory			44	51	53		119	165	216	184	832
Buff			29	41	51		90	91	95	94	491
Brown			15	12	30		47	38	41	40	223
Red			4	6	8		12	18	14	13	75
Total			105	130	180		305	389	448	392	1,949

The data in the upper half of this chart were secured on July 31, 1927. The night was clear and cool. The temperature was 69° at 9:00 and 66° at 10:00 P. M. The humidity was 45, which was very low. The data in the lower half of the chart were taken on July 18. The temperature was 76° at 9:00 and 78° at 10:00 P. M. Unfortunately no psychrometer was available so no humidity records were taken. These readings were taken at consecutive 15- or 30-minute intervals. The light was not turned off.

for the apparatus, ground level, 1½ ft., 3 ft. and 10 ft. The 1½ and 3 ft. levels proved most satisfactory. The colored electric light bulbs were the round 25-watt type of the following colors arranged in order, red, brown, buff, ivory, green and blue. They were ordinary outside colored bulbs that can be purchased at any electrical shop. The bulbs were not corrected for intensity of wave length. The physicist at the General Electric Laboratories at Nela Park, Cleveland, Ohio, informed me that the cost of having them calibrated would be unwarranted for a cheap bulb, as it would not hold constant long enough for practical use; hence, the bulbs were used as they came from the shop.

The apparatus after being placed in various locations was permanently set up on the lawn of the laboratory. A corn field adjoined the yard and all around were maple trees with a few fruit trees, such as apple, pear, cherry and plum.

RESULTS.

The summer of 1930 presented some very interesting comparisons. There was a period when the hot, dry conditions at Oak Harbor, Ohio, were similar to those in the desert (unpublished data). Following this, 3.04 inches of rain fell during three rains from July 21 to July 26 and that constituted the rain for the season. This was followed by another hot period from July 28 to August 4, when it turned cool and remained so for the rest of the summer. During the latter part of the season heavy dews occurred.

From a study of Table III it is seen that ivory attracted 453 leafhoppers out of a total of 909. Green was second in place of attractiveness, with brown, buff and red following in the order named. This same order of attractiveness was true for the corn borer. The reason that blue, a bulb normally expected to hold an attraction for insects, did not receive any is because the color covering on the bulb does not permit the transmission of the same intensity of light as that of the other bulbs. The correlation between color of light and response of leafhoppers is .55.

The odds calculated from the formula $t = \frac{r}{\sqrt{1-r^2}} \times \sqrt{n^1+2}$ as given by Fisher are 3,333,332 to 1 that there is a significant correlation.

TABLE III.

SHOWING THE RESPONSE OF LEAFHOPPERS TO COLORED BULBS. 1930.

COLOR OF BULB	DATES THAT EXPERIMENTS WERE CONDUCTED AND NUMBER OF LEAFHOPPERS RESPONDING																									Total
	June			July																				August		
	25	27	30	2	3	7	9	10	11	14	16	17	18	21	22	23	24	25	26	28	30	31	1	4	
Brown	9	5	1			5	3	9	11				31							11	4			36	125
Buff	8	8	3			8	6	7	13				16							20	3			31	123
Green	12	6	11			8	14	4	10				36							36	5			20	162
Red	3	0	0			1	5	6	0				9							6	4			12	46
Ivory	22	12	30			26	35	12	33				106							84	10			83	453
Blue	0	0	0			0	0	0	0				0							0	0			0	0
Total	44	31†	45			48	63	38	67				198							157	26			182	909
Temp. 8:00 P. M.	71	73	78	68	64	75	70	73	74	58	70	80	89	68	74	71	81	82	77	86	70	70	70	83	
Temp. 10:00 P. M.		69	72	58	53	66	69	72	69	52	66	73	82	72	72	67	72	75	74	83	63	64	66	77	
Average	71	71	75	63	58.5	70.5	69.5	72.5	71.5	55	68	76.5	85.5	70	73	69	76.5	78.5	75.5	84.5	66.5	67	68	80	
Humidity 8:00 P. M.	‡	46	63	83*	83*	64	67	66	74	83*	70	56	37	‡	‡	83*	‡	‡		56	84	83*	75	82	
Humidity 10:00 P. M.	‡	72	‡	83*	83*	‡		69	90	83*	90	‡	41	‡	‡	83*	‡	‡		75	84*	83*	67	77	
Average	‡	59	63	‡	‡	64	67	67.5	82	‡	80	56	39	‡	‡	‡	‡	‡		65.5	‡	‡	71	79.5	
Average wind velocity, 8–10	1.1	5.2	2.8	4.0	1.2	*none*	.9	2.1	1.2	2.4	2.8	2.8	*none*	3.1	1.8	.9	.6	.6	.6	.6	*none*	1.0		*none*	
Rain								.05						.96	.38				2.70						

†Quit at 9:00 P. M., when wind increased.
*Humidity was too high at the beginning of the experiment.
‡Hygrothermograph registered above 90 percent.

Referring again to Table III, the odds according to Fisher's formula $t = \frac{\bar{x}-\bar{x}_1}{s}\sqrt{\frac{(n_1+1)(n_2+1)}{n^1+n^2+2}}$ that the differences between the colored lights are significant is shown by the following:

The odds are 121 to 1 that there is a significant difference between ivory and green, but the difference is not great enough to show significant odds for green light compared with brown. The same is true for brown and buff, two colored bulbs which are very much alike, but the odds are 92.2 to 1 that buff is more attractive than red.

Ordinary 25-watt clear glass, mill type electric light bulbs attract leafhoppers but not as much as a 100-watt Mazda C. No leafhoppers were collected from these bulbs, but counts

TABLE IV.

SHOWING THE COMPARISON BETWEEN CLEAR GLASS BULBS AND COLORED BULBS.*

DATE	BROWN	BUFF	GREEN	RED	IVORY	BLUE	25 WATT CLEAR	50 WATT CLEAR	TOTAL
June 30	1	3	11	0	30	0	2	8	55
July 7	5	8	8	1	26	0	5	11	64
July 9	3	6	14	5	35	0	8	18	89
July 10	9	7	4	6	12	0	2	3	43
July 11	11	13	10	0	33	0	2	8	77

*Counted but not collected.

were made. The results are tabulated in Table IV. In no case did the clear glass bulb attract as many as the ivory. On two occasions the 50-watt clear glass bulb attracted more than the green light.

It was repeatedly observed on nights that were not good for conducting the tests that leafhoppers came to windows through which the light from a 40-watt Mazda inside frosted bulb was shining. The leafhoppers were collected but in no instance did more come the same night. It is possible that when the lights were turned on in the room, the reflection through the window attracted those in proximity and they all came within a short period of time. The fact that once they were collected no more came to the window seems to confirm the above statement.

Table V shows the name and number of leafhoppers collected at each light. The determinations were made by Prof. Herbert Osborn.

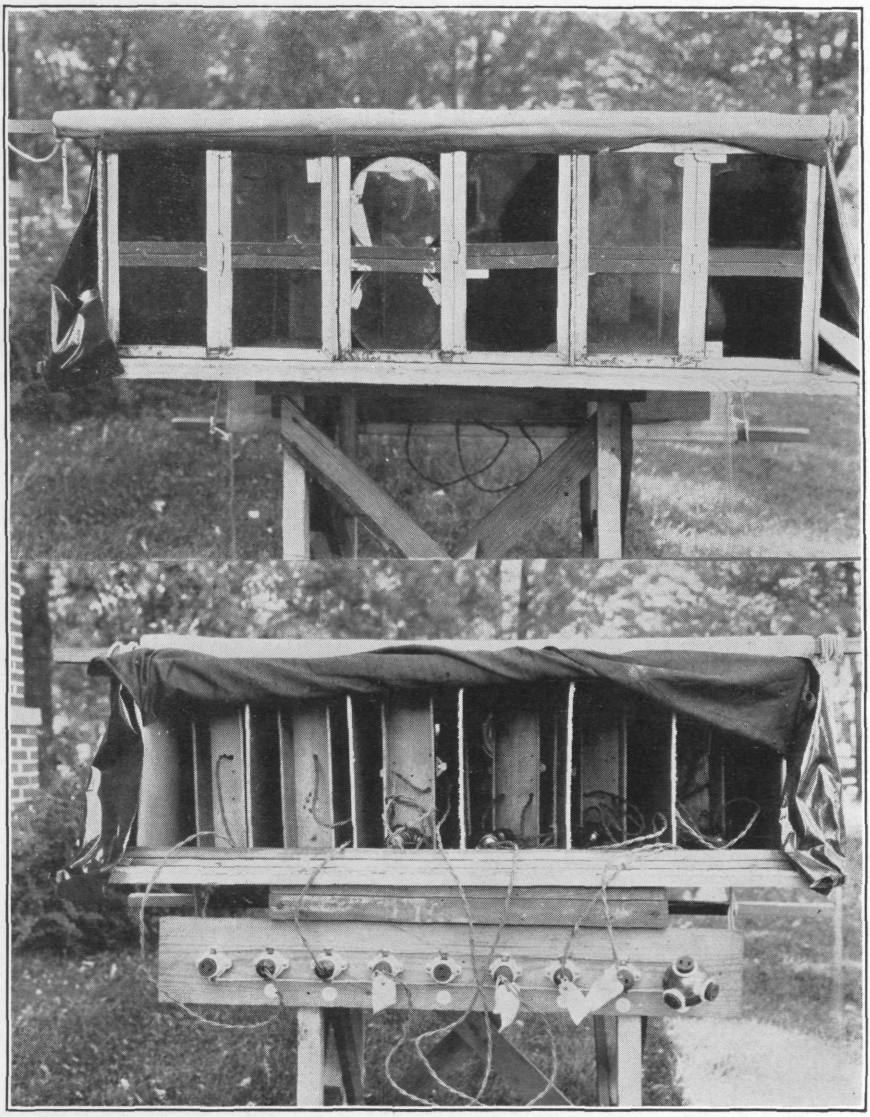
Due to the small numbers, no correlation can be made between species and color of light. From a study of the table, the first four species had the same relative attractiveness to the lights with no significant differences.

TABLE V.

SHOWING THE NAME OF LEAFHOPPERS WITH NUMBER COLLECTED AT THE COLORED BULBS. 1930.

NAME OF LEAFHOPPER	IVORY	GREEN	BROWN	BUFF	RED	TOTAL
Phlepsius irroratus	117	60	50	48	14	289
Deltocephalus inimicus	106	27	15	19	11	178
Cicadula 6-notata	80	46	9	7	6	148
Empoasca fabae	29	3	0	2	1	35
Thamnotettix nigrifrons	9	0	0	3	0	12
Scaphoideus immistus	6	0	1	0	1	8
Dikraneura fieberi	7	0	0	0	0	7
Xestocephalus pulicarius	4	1	0	0	0	5
Gypona octolineata	0	2	1	0	0	3
Chlorotettix galbanata	1	2	0	0	0	3
Eutettix seminudus	0	0	0	2	0	2
Thamnotettix clitellarius	1	0	0	0	1	2
Dikeanura sp.	0	2	0	0	0	2
Draeculacephala inscripta	0	0	2	0	0	2
Draeculacephala mollipes	2	0	0	0	0	2
Idiocerus pallidus	0	0	0	1	0	1
Idiocerus suturalis	1	0	0	0	0	1
Gypona pectoralis	0	0	0	1	0	1
Totals	363	143	78	83	34	701

In 1931, in addition to the experiments with colored bulbs, the leafhoppers were also exposed to different wave lengths of light. The field apparatus consisted of a box framework which held six ray filters in their respective tin frames. The filters were 6½-inch squares manufactured by the Corning Glass Company. The colors and numbers of the filters were as follows: Red purple ultra, G586A; light blue green, G584J; signal purple, G55A; blue purple ultra, G585L; Pyrex and heat absorbing, G124J. The general set-up of the apparatus may be seen from the photographs (Plate I).



METHODS.

The light apparatus was set in a back yard with the following existing conditions: The lawn was mowed in front and back of the apparatus. On one side was a blackberry patch and garden while on the other, a grape arbor and garden. To the extreme front was another blackberry patch and garden, while the trees surrounding the area were soft maple, hickory, apple, pear and cherry.

Quantitative leafhopper counts were made at 15-minute intervals instead of mass collecting. The lights were turned on for 15 minutes and after the reading was taken they were turned off for the same period. In this manner a quantitative sample was taken and the period of flight determined.

RESULTS.

The season of 1931, although very well adapted for corn borer work, was not so good for night collecting. In 1930 there was a total of 3.09 inches of rain from June 25 to August 4 and 3.05 inches for the same period in 1931. However, in 1930, 3.04 inches of this rain came in three rains between July 21 and July 26, constituting the rainfall for the summer of 1930. In 1931 the same amount of rainfall was spread over the whole period. Although anemometer readings were not taken during 1931 there was noticeably more wind than in 1930.

A total of 5.59 inches of rain fell during the period from August 4 to September 16. The whole summer of 1931 was characterized by nights with heavy dew.

The 1931 colored bulb light experiments agree with those of 1930. See Table VI. There was not sufficient data for the 1931 tests with ray filters to draw any conclusions. However, from the results obtained pale blue green attracted 32 leafhoppers while pyrex was second with 25. The attractiveness of the other lights was as follows: Signal purple 23, purple ultra 16, heat absorbing 12, and red purple ultra 4. Of all the lights red purple ultra transmits the most ultra and attracts less leafhoppers. Pale blue green is the only filter not extending into the red end. Pyrex is a neutral glass and allows all rays to go through; so it is to be expected that the red end will offset the blue end. Signal purple and blue purple ultra transmit a band of red. Heat absorbing has a wide range and transmits rays of red as well as blue.

Leafhoppers responded to lights so long as the humidity

remained under 83 percent, but when the humidity increased above that point they ceased coming to the light. However, those already at the lights remained there. So far, the hiding places of the leafhopper at night have not been found.

A high temperature and low humidity are best suited for leafhopper response to light, but a high humidity, so long as it does not pass 83 percent, draws many leafhoppers. Referring to Table III it will be noted that nights having a high humidity did not attract leafhoppers. A combination of low temperature and high humidity is inimical to leafhopper attraction.

TABLE VI.

SHOWING THE RESPONSE OF LEAFHOPPERS TO COLORED BULBS. 1930.

COLOR	NUMBER OF LEAFHOPPERS TAKEN							TOTAL
	June 25	July 8	July 10	July 13	July 27	July 28	July 30	
Red	10	4	1	6	0	3	4	28
Buff	27	5	5	8	1	4	10	60
Brown	33	3	6	8	0	6	10	66
Ivory	48	20	10	36	4	11	33	162
Green	19	8	7	23	1	7	21	86
Total	137	40	29	81	6	31	78	402
Temp. 8:00 P. M.	82	83	75	73	72	82	88	
Temp. 10:00 P. M.	78	78	71	71	71	81	84	
Average	80	80.5	73	72	71.5	81.5	86	
Humidity 8:00 P. M.	76	80	88	73	82	68	60	
Humidity 10:00 P. M.	80	70	78	79	82	69	76	
Average	78	75	83	76	82	68.5	68	

Wind direction is important, but wind velocity is much more so. The apparatus was so designed to face the prevailing wind. Leafhoppers do not respond on nights when velocity is over 3½ miles per hour.

Catalepsy has not been observed in the leafhopper. Another interesting thing observed was that if conditions were favorable for a good leafhopper night, the insects would come to the lights despite the fact that the operator or others might be in the immediate vicinity.

Entomologists have reported occasional flights of leafhoppers at night. This habit of night flight is not restricted to any one species but represents a number of genera. No migration or exceptionally heavy flight was noticed such as occurred in 1927.