RESPONSE OF EUROPEAN CORN BORER[1] MOTHS TO COLORED LIGHTS

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INTRODUCTION

One of the most frequent questions and one of the most difficult to answer for those connected with corn borer research problems is that which concerns the phototactic responses of the adult or moth. The common impression that all insects are attracted to lights has led to the assumption that corn borer moths could be trapped in sufficient numbers to aid materially in the control of this pest. The fact that the moths are night fliers has further strengthened this assumption.

Because there was a general demand for definite information on this point, it was decided in 1926 to inaugurate investigations dealing with this phase of the problem. The data accumulated constitute the subject matter of the present discussion.

THE PROBLEM

Field and laboratory work was so outlined as to endeavor particularly *to determine the influence of lights of different colors on the behavior of the insects.*

MATERIALS AND EQUIPMENT

Description of Filters Used

Several filters, each 6½ inches square, were used in the colored light tests. These ray filters were manufactured by the Corning Glass Works, Corning, N. Y.

The code numbers for all of the filters have been changed since the work was started. Table I shows the wave-length, name, and number of the filters. It will be noted that the G34 and G24 used in these experiments have been subdivided, the visible transmission being determined by the position of the spectral cut-off. A brief description of each filter follows:

Pyrex.—This glass now known as Heat Resisting Clear Chemical Class No. 774 has medium ultra-violet transmission

[1]*Pyrausta nubilalis* Hubn.

and is highly transparent to visible radiation. The pyrex filter used in the tests transmitted light more freely than any other used; so the factor 1.0 was designated as the basal unit for calculating the transmission value of all the others.

Pale Blue Green.—This glass is now known as Light Shade Blue Green No. 428 and has the greatest ultra-violet transmission of any blue green glass available. It requires 9.61

TABLE I

Showing Filter Number with Present Name and Code Number*

Old Number	New Number	Wave Length
G86B	Discontinued—now H. R.† Clear Chemical Glass, No. 774	295–780
G38H	Noviol Shade C, No. 338	480–720
G38L	Noviol Shade O, No. 306	380–720
G34	Covers a series of glasses as follows	525–780
	H. R. Red Shade Yellow, No. 348.	
	H. R. Lantern Shade, No. 349.	
	H. R. Yellow Shade, No. 351.	
G24	Covers a series of glasses as follows	600–780
	H. R. Signal Red, No. 243.	
	H. R. Lantern Red, No. 244.	
	H. R. Traffic Red, No. 245.	
	H. R. Lighthouse Red, No. 246.	
G124J	Discontinued—Now H. A. Green, No. 492	320–780
G584J	Light Shade Blue Green, No. 428	300–660
G585L	Blue Purple Ultra, No. 585	290–485
G586A	Red Purple Ultra, No. 597	300–420
G55A	Signal Purple, No. 555	300–560

*The above information was furnished by D. L. Killigrew, Aviation and Optical Division of the Corning Glass Works. The wave length data were calculated from Sayre (5).

†H. R.—Heat Resisting.

times as much light as does pyrex for producing transmitted light of equal intensity; therefore, the ratio of intensity is 9.61 to 1.

Noviol O.—This filter is used to absorb ultra-violet, to eliminate haze and thus improve visibility both in visual and photographic work, and, in general, as a selective ray filter. The ratio of intensity is 1.14 to 1.

Noviol C.—This glass is characterized by the sharp transition between high transmission and strong absorption and is used to absorb ultra-violet. The ratio of intensity is 1.41 to 1.

Heat Resisting Yellow.—The old G34 filter used in these experiments covers a series of glasses as follows: H. R. Red

Shade Yellow No. 348, H. R. Lantern Shade No. 349, and H. R. Yellow No. 351. These are low expansion, heat resisting glasses with a sharp spectral cut-off ranging from red orange to lemon yellow, depending upon the position of the spectral cut-off. The ratio of intensity is 1.25 to 1.

Blue Purple Ultra.—This filter transmits .365 μ ultra-violet, .405 μ violet, .435 μ blue, and extreme red beyond .72 μ. The ratio of intensity is 3.07 to 1.

Heat Absorbing.—The blue green glass of this filter is effective for obstructing the infra-red, although it is not well adapted for absorbing the visible rays. The ratio of intensity is 2.18 to 1.

Signal Purple.—Both ends of the spectrum are transmitted. The ratio of intensity is 10.5, placing it slightly lower than Pale Blue Green.

Red.—The old G24 filter used in these experiments covers a series of glasses as follows: H. R. Signal Red No. 243, Lantern Red No. 244, H. R. Traffic Red No. 245, and H. R. Lighthouse Red No. 246. Inasmuch as the type of glass has nearly complete transparency for the longer wave-lengths, the visible transmission is determined mostly by the position of the spectral cut-off. The ratio of intensity is 2.45 to 1.

Red Purple Ultra.—This glass transmits .365 μ ultra-violet freely, .405 μ violet, and extreme red at about .72 μ. This filter has the lowest light intensity of any used in the tests, its ratio being 47.6 to 1.

Bulbs

Clear electric light bulbs of the strengths 10, 15, 25, 50, and 100 watts manufactured by the Mazda National Lamp Works (General Electric Co.) were employed in all of the tests. The 10-watt bulbs were 115V S14 Mazda B; the 15-watt bulbs were 115V S17 Mazda B; the 25- and 50-watt were 115V mill type P19; and the 100-watt were 115V PS25 Mazda C. Except in the 15-watt bulb, in which the filament was mounted straight, the filament in all the other bulbs used was mounted in the form of a helix. The advantage of using a lamp of the latter type is that the light is emitted in a straight line and not at an angle. The brilliance of a coiled filament is greater than that of a straight filament, due to the lesser projected area and the reflections from the inside of the coil.

When 50-watt and 10-watt bulbs were used together, it was evident that the filaments would not be even; so the lights were mounted on adjustable holders to insure centering and compensating for intensity.

Assembled Apparatus

The apparatus used was in the shape of an oblong, rectangular box, 66″ long, 7″ high, and 18″ wide. (See Figure 1.) Ten filters were mounted in frames on one side. Screen wire

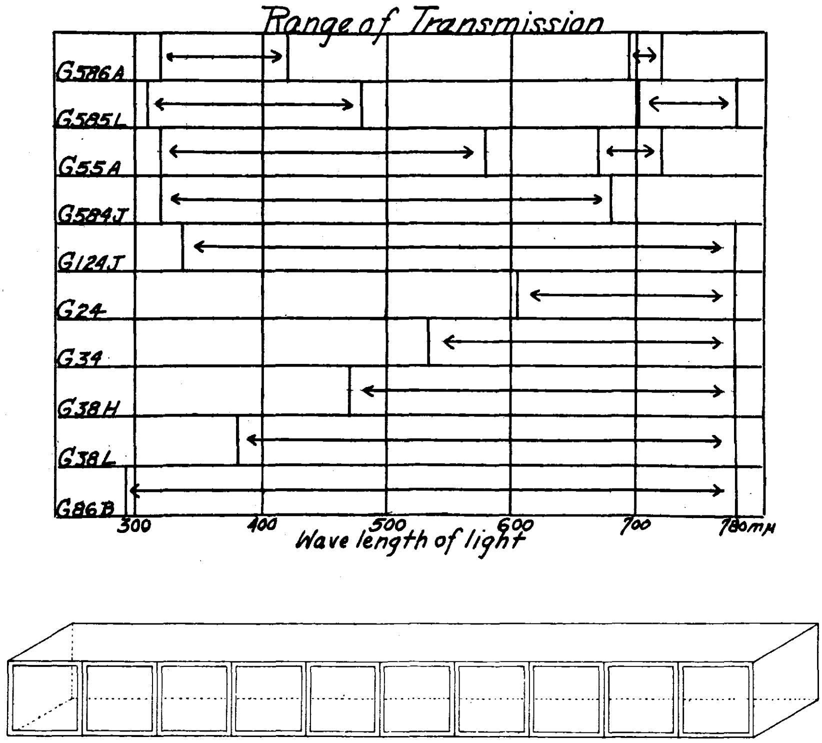

FIGURE 1

covered the top of the box, and a door in the wall opposite the filters permitted the introduction of the moths. The lights were arranged back of the filters on the outside of the test box and partitions separated them. The top was not covered.

The filters in this apparatus were arranged according to the way they are listed in Table II; that is, according to wave length. All of the calculations were made on the basis of 100. Thus Pyrex, the neutral glass, is placed in the center with the filters having short wave-length on one side and those of longer wave-length than the pyrex on the other side, arranged in order of their wave-length. All lights were corrected for intensity.

TRANSMISSION DATA

The transmission data for the glass filters were obtained from the Bureau of Standards Technologic Papers by Coblentz and Emerson (1), Gibson and McNicholas (3), Gibson, Tyndall, and McNicholas (4), and Sayre (5). Gibson and McNicholas (3) present a chart and give instructions for converting these data which are for an equal energy spectrum. When the areas under the transmission curves were plotted on cross-section paper and compared, the percentage of total transmission for each filter was obtained. These data were calculated for a spectrum extending from 290 mμ to 780 mμ. (Fig. 1.) Gibson and McNicholas (3) give 770mμ as the limit of visible spectrum.

TABLE II

SHOWING RELATIVE DISTRIBUTION OF WAVE LENGTHS FOR CERTAIN FILTERS

Filter	+ Short	— Short	Median	+ Long	— Long
Red Purple Ultra	63	16	....	5	16
Pale Blue Green	22	27	27	22	....
Signal Purple	28	35	28	5	4
Blue Purple Ultra	36	32	....	....	32
Pyrex	20	20	20	20	20
Heat Absorbing	14	23	23	23	18
Noviol O	5	25	25	25	20
Noviol C	....	10	32	32	26
H. R. Yellow	....	....	27	41	32
Red	....	....	....	53	47

The transmission curves for the filters are shown in Fig. 2 and are applicable only for filters of the thickness indicated in each case. The transmission of a specimen, as stated by Gibson, Tyndall, and McNicholas (4), is that fraction of radiant energy incident on the first surface which gets through the second surface. In a comparison of the transmissions of different glasses, due account must be taken of the variation in thickness. It was not necessary to have the filters photographed and their range of spectrum calculated because the graphs given by the Bureau of Standards paper and by Sayre are sufficiently accurate for the filters used in this discussion.

RELATIVE SPECTRAL DISTRIBUTION OF RADIANT ENERGY

Each screen varied considerably in the amount of light energy that is transmitted. The percentage of energy from the light transmitted by each filter was found by calculation.

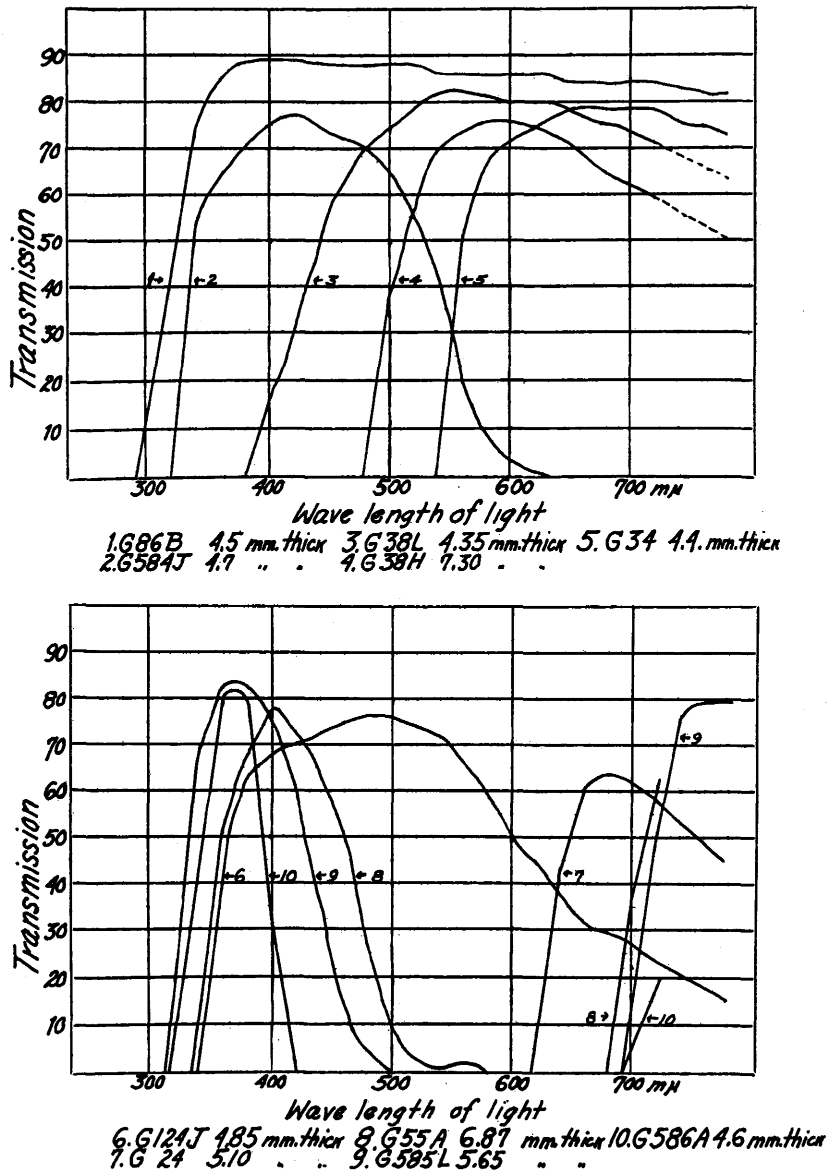

FIGURE 2

The data for the relative spectral distribution of radiant energy from 10-, 25-, and 50-watt Mazda B and 100-watt Mazda C bulbs were calculated from the curve given in General Electric bulletin Ld-114C. (7) (Figure 3.) The transmission value

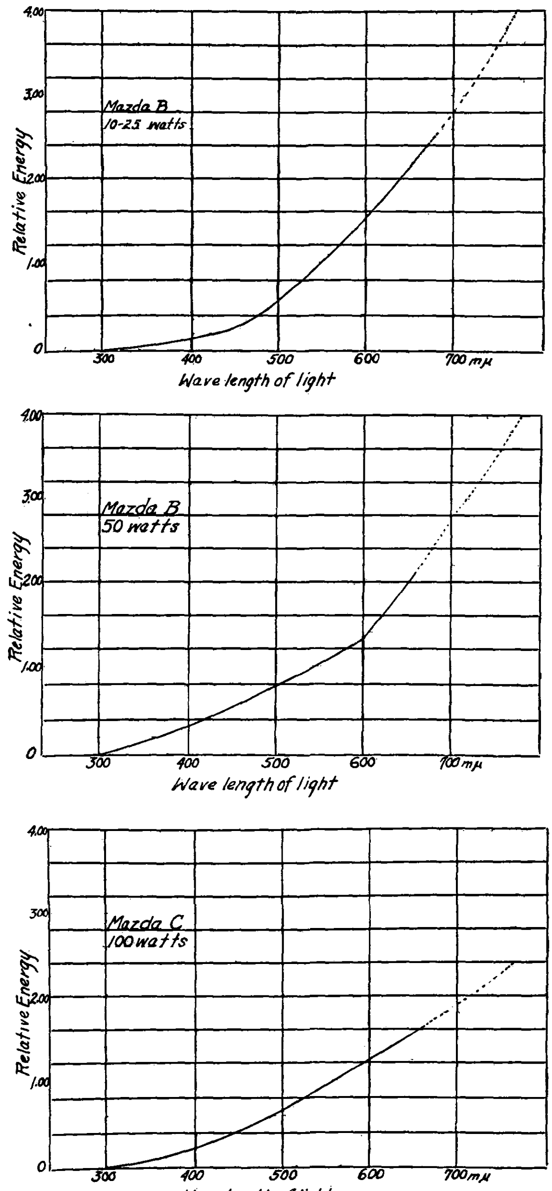

FIGURE 3

at each wave-length was multiplied by the values of relative spectral distribution of energy from the light. The areas under each curve were compared and reduced to percentages. The area of each curve thus measured is in proportion to the amount of light transmitted by a filter from bulbs of the same size placed at the same distance from the filter. These data are also applicable to Mazda lamps with inside frosted bulbs. In other words, the use of the frosted bulb does not introduce in the light output any factor that is not present in the clear glass bulb. The light is merely diffused and suffers a very small reduction in total quantity.

In a letter from General Electric Co., Harrison, N. J. (now Nela Park, Cleveland, Ohio), it was stated that "with the clear glass bulb it is apparent that the projected area of the light source; that is, the filament only, is small as compared to the projected area of the light source when an inside frosted bulb is used. In the latter case the entire bulb is considered as the source of light and hence its unit brilliancy is of a very much lower order than that encountered with the use of a clear bulb. In figures, the brilliancy of the inside frosted bulb is not over 2 per cent of that of a clear bulb."

SOURCE OF MOTHS USED IN THE WORK

All of the moths used in the laboratory tests were obtained from pupae which, as larvae, had spun up in corrugated paper strips. The paper strips containing the pupae were placed in large screen containers; the emerging moths were then collected from these and placed in smaller cages having a capacity of one hundred moths. The moths were kept for a period of 4 to 6 hours in a dark room of the same temperature and humidity as the one in which the light tests were conducted. The average temperature was 82° F. and the average humidity was 64 per cent. The boxes containing the moths were kept covered with damp cloths.

TECHNIQUE

Trial tests were conducted to determine the most satisfactory routine to be followed in introducing the moths into the light chamber. Lots of 100 moths each were placed in a compact wooden box with a screen wire cover. The sexes were kept separate. In some instances the moths were introduced at the end of the light chamber in which the short light waves predominated; in other instances they were liberated in the end where the long light waves predominated; in still others they were released in the center of the box opposite the pyrex or neutral end.

The reactions of the moths were highly specific in that the insects introduced in the vicinity of the filters emitting light of short wave-lengths or in the center of the chamber opposite the neutral light exhibited a marked tendency to seek out the short wave-length lights. After a number of such trials it was finally decided that the most satisfactory point of introduction

TABLE III

SHOWING THE RESPONSE OF MALE EUROPEAN CORN BORER MOTHS TO COLORED LIGHTS

Replicates	Red Purple Ultra	Pale Blue Green	Signal Purple	Blue Purple Ultra	Pyrex	Heat Absorbing	Noviol O	Noviol C	H. R. Yellow	Red	Total
1	25	18	7	3	8	2	1	1	1	0	65
2	14	10	10	5	6	1	0	2	2	0	51
3	13	17	4	4	4	1	0	0	0	0	43
4	22	15	12	4	2	1	0	0	0	0	56
5	23	12	7	5	3	1	0	0	0	1	52
6	13	8	11	2	4	3	4	0	0	1	46
7	8	12	18	3	3	0	0	0	0	0	44
8	11	8	10	5	5	2	2	2	2	0	45
9	4	9	5	3	6	2	1	1	1	0	32
10	30	14	12	6	5	2	1	0	0	3	73
11	19	14	14	5	7	3	2	1	1	1	67
12	7	7	10	9	8	4	0	0	0	0	45
Total	189	144	120	54	61	22	11	7	5	6	619
Mean	15.8	12.0	10.0	4.5	5.0	1.8	0.9	0.6	0.4	0.5	

was in the center of the cage opposite the Pyrex or neutral light. It is possible, however, that this procedure may have unduly influenced the number of insects going to Pyrex, since a study of Tables III and IV shows a slightly larger number of moths attracted to Pyrex than to the theoretically more attractive and immediately adjoining light, Blue Purple Ultra. Moreover, the difference in the number of moths selecting Pyrex and those selecting the adjoining, less attractive Heat Absorbing was greater than theoretically would have been expected.

The tests were replicated many times, and before each trial the entire apparatus was carefully checked in order that the same adjustment obtained for all tests. The lights in the room, except those connected with the apparatus, were extinguished while each test was in progress.

At the outset, it was not known how much time should be allowed the moths to complete their response. After a number of trials it was found that if the insects were given 20 minutes in which to adjust themselves, little change in position occurred thereafter; hence this period was used as the interval allowed for response throughout the work.

TABLE IV

SHOWING THE RESPONSE OF FEMALE EUROPEAN CORN BORER MOTHS TO COLORED LIGHTS

Replicates	Red Purple Ultra	Pale Blue Green	Signal Purple	Blue Purple Ultra	Pyrex	Heat Absorbing	Noviol O	Noviol C	H. R. Yellow	Red	Total
1	17	22	6	4	6	6	0	0	0	0	61
2	12	11	8	7	6	2	1	0	1	0	48
3	22	11	9	7	6	1	1	1	0	0	58
4	22	16	8	3	4	0	0	0	1	1	55
5	21	17	8	3	6	0	0	0	0	0	55
6	16	11	7	5	4	2	0	0	0	0	45
7	7	14	9	5	5	2	1	3	0	0	46
8	10	12	6	4	4	1	0	0	1	0	38
9	11	11	10	7	8	3	1	2	0	0	53
10	11	9	7	6	7	2	0	0	0	1	43
11	16	12	10	6	13	1	2	2	0	1	63
12	6	11	5	6	4	2	1	0	0	2	37
Total	171	157	93	63	73	22	7	8	3	5	602
Mean	14.3	13.1	7.8	5.3	6.1	1.8	0.6	0.7	0.3	0.4	

After the moths had once selected a light chamber, they were not easily disturbed, even though at the conclusion of an experiment the colored lights were extinguished and the room lights turned on directly above the apparatus.

RECORDED RESPONSES OF MOTHS AND ANALYSIS THEREOF

A study of Tables III and IV reveals the fact that the moths respond to the colors in order of their descending wavelengths. Reference to Table II shows that Red Purple Ultra has 63% of its transmission in the short + end, 16% in short −, nothing transmitted in the median, 5% in long+, and 16% in long −. This is in accordance with the description of the filter which states that it transmits .365 μ ultra-violet freely, .405 μ violet, and extreme red at about .72 μ. Pale Blue Green was very close to Red Purple Ultra in order of response, which may be explained by reason of Pale Blue Green transmitting farther into the ultra-violet than any other blue green glass available. There is a marked difference from these on down in the table. Signal Purple transmits 5% in long + as compared with Pale Blue Green 22%, but this is offset by a transmission in long −. Blue Purple Ultra has 36% transmission in short +, 32% in short −, and 32% in long −, which corresponds to its description as transmitting .365 μ ultra-violet, .405 μ violet, .435 μ blue, and extreme red beyond .72 μ. There is a sharp drop in response from Pyrex to Heat Absorbing. Noviol O, Noviol C, H. R. Yellow, and Red are about equal in order of response to the moths. Owing to the small numbers of moths responding, no explanation is offered for the fact that Red receives more moths than H. R. Yellow.

According to Fisher's (2) method of analysis of variance, there are significant differences in response of moths to wave length. In Tables II and III the means are given under each total. Using Fisher's table (where $t = \frac{(n_1 + 1) + (n_2 + 1)}{(n_1 + 1) + (n_2 + 1)}$) a difference of 2.805 for Table II must exist between the succeeding differences of the means of the response of male moths to wave-length before they are significant. Thus, for example, there is a difference of 3.8 between Red Purple Ultra and Pale Blue Green; hence, this difference is significant. In Table III the difference is 2.04, and for the combined male and female is 3.995.

CONCLUSIONS

When the filters were arranged in the apparatus in the ascending or descending order of wave-length, and the light transmitted through the filters was in all instances of uniform or comparable intensity, the moths responded in significantly greater numbers to the lights of short wave-length than to those of long wave-length; that is, the blue light of the series attracted more moths than did the red light on the opposite end of the series.

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