THE RHINOCEROS BEETLE *(ORYCTES RHINOCEROS L)* IN CEYLON

PART II C—Phototaxic responses of (*Oryctes rhinoceros L*)
Comparative study of the responses to " Coloured light," " No light " and " White light ".

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Introduction

Parts II A and B

In Part II A and Part II B of this study, the senior author *et. al.*, have reported the responses of *Oryctes rhinoceros* to coloured light as against white light (as emitted through ground glass) and to coloured light as against no light. In this study we are endeavouring to analyse the possible implications of the previous studies referred to above on a comparative basis.

The analysis in Parts II A and B, was on the basis of percentage attracted to different colours, both the ground glass and no light serving merely as controls. The statistical index used was the number of beetles attracted to each colour expressed as a percentage of the total number of beetles used in the experiment. As against this, the statistical index used in the present study is number of beetles attracted to a particular colour expressed as a percentage of the total number of beetles attracted to the colour as well as the alternate choice. The implications of the present statistical index is that we now study the response of beetles when offered two alternative choices.

Materials and Methods

The material used in the experiment is described in detail in both Parts II A and B.

Although no particular standard design was employed the experiment conformed to certain requirements and can therefore lend itself to statistical treatment.

A series of experiments were conducted using one colour filter at a time against an alternative choice of entry in the form of "ground glass". Another series of experiments followed, again using one colour filter at a time against another alternate choice of entry in the form of no light.

Between the testing out of each filter in the experiment a period of time (24 hours) was allowed as a " fallow period " so as to permit the reactions of the beetles to return to normal. Each series was replicated thrice with a time interval between each series.

Results

Table I gives the number of beetles attracted in each of the three replicates according to sex, to colour and to the alternate choice of entry.

TABLE I

The incidence of beetles according to sex to colour and form of alternate choice of entry

Colour	Replicates	*Male*		*Female*		*Male*		*Female*	
		Ground Glass	*Coloured light*	*Ground Glass*	*Coloured light*	*No Colour*	*Coloured light*	*No Colour*	*Coloured light*
..	1	8	11	12	14	12	3	15	4
Red ..	2	6	10	3	5	5	3	10	7
..	3	4	10	1	7	8	4	9	11
..	1	13	5	11	10	2	4	6	8
Blue ..	2	5	8	5	3	1	2	6	7
..	3	1	4	2	3	1	3	6	8
..	1	7	5	12	10	5	5	5	8
Neutral ..	2	4	3	7	7	8	2	6	5
..	3	5	5	3	3	6	4	9	4
..	1	7	0	7	8	3	5	8	3
Green ..	2	4	5	7	2	4	2	10	2
..	3	3	2	1	3	5	3	4	6
..	1	3	5	5	6	1	2	3	1
Orange ..	2	5	0	2	1	2	3	2	1
..	3	2	1	3	0	5	2	3	0
..	1	1	0	4	5	5	0	5	1
Purple ..	2	2	3	1	3	3	4	4	1
..	3	0	2	0	2	2	0	1	1
..	1	3	0	5	4	0	3	1	7
Yellow ..	2	1	0	3	4	5	0	6	0
..	3	2	2	1	4	4	2	1	1

TABLE II

Percentage of beetles attracted to colours against the alternate choice

Colour	*Alternate Choice*	*Replicate* 1		*Replicate* 2		*Replicate* 3	
		Male	*Female*	*Male*	*Female*	*Male*	*Female*
Red	Ground glass	57.9	53.8	62.5	62.5	71.4	87.5
	No colour	20.0	21.1	37.5	41.2	33.3	55.0
Blue	Ground glass	27.8	47.6	61.5	37.5	80.0	60.0
	No colour	66.7	57.1	66.7	53.8	75.0	57.1
Neutral	Ground glass	41.7	45.5	42.9	50.0	50.0	50.0
	No colour	50.0	61.5	20.0	45.5	40.0	30.8
Green	Ground glass	50.0	53.3	55.6	22.2	40.0	75.0
	No colour	62.5	27.3	33.3	16.7	37.5	60.0
Orange	Ground glass	62.5	54.5	0	33.3	33.3	0
	No colour	66.7	25.0	60.0	33.3	28.6	0
Purple	Ground glass	0	55.6	60.0	75.0	00.0	100.0
	No colour	0	16.7	57.1	20.0	0	50.0
Yellow	Ground glass	0	44.4	0	57.1	50.0	80.0
	No colour	100.0	87.5	0	0	33.3	50.0

All data in the form of percentages have been subjected to the inverse sine transformation in order to secure the validity of the analysis of variance. The calculation consists of ascertaining angle θ corresponding to the observed value of proportion P, such that sine θ = P.

Table III gives the transformed values.

TABLE III

Transformed percentages of beetles attracted to colours as against the alternate choice

Colour	*Alternate Choice*	*Replicate* 1		*Replicate* 2		*Replicate* 3	
		Male	*Female*	*Male*	*Female*	*Male*	*Female*
Red	Ground glass	35	33	39	39	46	61
	No colour	12	12	22	24	20	33
Blue	Ground glass	16	28	38	22	53	37
	No colour	42	35	42	33	49	35
Neutral	Ground glass	25	27	25	30	30	30
	No colour	30	38	12	27	24	18
Green	Ground glass	0	32	34	13	24	49
	No colour	39	16	20	10	22	37
Orange	Ground glass	39	33	0	20	20	0
	No colour	42	15	37	20	17	0
Purple	Ground glass	0	34	37	49	90	90
	No colour	0	10	35	12	0	30
Yellow	Ground glass	0	26	0	35	30	53
	No colour	90	61	0	0	20	30

The analysis of variance was carried out on the transformed value for the main effects (colour, sex and alternate choice) and their interactions.

TABLE IV

Analysis of Variance

Source	*DF*	*SS*	*MS*	*F*
Replicates	2	1372	686	—
Main effects				
Colour	6	1961	327	—
Sex	1	78	78	—
Alternate choice ..	1	750	750	2.19
Interactions				
Colour × Sex	6	1327	221	—
Colour × Alternate choice ..	6	4919	820	2.39*
Sex × Alternate choice ..	1	680	680	1.98
Colour × Sex × Alternate choice	6	787	131	—
Error	54	18533	343	—
Total	83	30407	—	—

The interaction of colour × alternate choice is statistically significant.

When we consider the main effects we find as follows :—

1. Colour :

The analysis of variance shows that the main effect *colour* is not even suggestive of significance. This means then that if we take the average attracting effect of each colour, shown in the two series of experiments, in the case of each alternate choice of ground glass and no colour, there is no significant difference between colours as such.

TABLE V

Colour Means

Colour	*Percentage attracted*	
	Transformed value	*Real value**
Red	31.3	52.0
Blue	35.8	58.5
Neutral	26.3	44.3
Green	24.7	41.8
Orange	20.3	34.7
Purple	32.3	53.4
Yellow	28.8	48.2

*retransformed.

Critical difference between colour means (transformed value) = 15.1.

2. Sex :

From the analysis of variance we see that the main effect *sex* is not even suggestive of significance. If we take the average attracting effect of *sex* over the two alternate choices and colours we see that there is no significant difference.

TABLE VI

Sex Means

Sex	*Percentage attracted*	
	Transformed value	*Real value*
Male	27.5	46.2
Female	29.5	49.2

Critical difference between *sex* means (transformed value) = 8.1.

3. Alternate choice :

The analysis of variance shows that the main effect *alternate choice*, although not significant at the conventional 5 per cent level, is suggestive of significance. It means therefore, that the average attracting effect against each alternate choice, over all colours and sex, does not differ strictly. However, there is a suggestion that the attraction to colour is greater when the alternate choice is ground glass than when the choice is no-colour.

TABLE VII

Means for Alternate Choice

Alternate choice	*Percentage attracted*	
	Transformed value	*Real value*
Ground glass	31.7	52.5
No colour	25.5	43.1

Critical difference between means (transformed values) of *alternate choice* = 8.1. We will now consider the implications of the interactions.

1. Colour × Sex :

No significance is shown up in the analysis of variance with respect to the interaction *colour* × *sex*. Therefore, there is no sex bias in the average attracting effect different colours over the two alternate choices.

TABLE VIII

Colour × Sex interaction

Colour	*Percentage attracted*			
	Male		*Female*	
	Transformed value	*Real value*	*Transformed value*	*Real value*
Red	29.0	48.5	33.7	55.5
Blue	40.0	64.3	31.7	52.5
Neutral	24.3	41.2	28.3	47.4
Green	23.2	39.4	26.2	44.2
Orange	25.8	43.5	14.7	25.4
Purple	27.0	45.4	37.5	60.9
Yellow	23.3	39.6	34.2	56.2

Critical difference between *colour* × *sex* means (transformed values) = 21.4.

2. Alternate choice × Sex :

Interaction of sex and alternate choice is not significant but it is slightly suggestive. We can conclude therefore that there is no strict sex bias in the attraction to colours with alternate choices. The suggestion that when the alternate choice is " ground glass," the average attraction to colours is greater in the females than males, cannot however be ruled out. In the case of males, more are attracted to " ground glass " than colour. If we consider the alternate choice of ground glass there is no sex bias and the average attraction in the case of each sex is greater towards no colour than to colour.

TABLE IX

Alternate choice × Sex interaction

Alternate choice	*Percentage attracted*			
	Male		*Female*	
	Transformed value	*Real value*	*Transformed value*	*Real value*
Ground glass	27.7	46.5	35.3	57.8
No colour	27.4	46.0	23.6	40.0

Critical difference between alternate choice × sex means (transformed value) = 11.4.

3. Alternate choice × Colour :

The analysis of variance shows that the interaction *alternate choice* × *colour* is statistically significant. This indicates that the response to different colours is dependent on or varies with the alternate choice.

TABLE X

Alternate choice × Colour interaction

Colour	*Percentage attracted*			
	Ground glass		*No light*	
	Transformed value	*Real value*	*Transformed value*	*Real value*
Red	42.2	67.2	20.5	35.0
Blue	32.3	53.4	39.3	63.3
Neutral	27.8	46.6	24.8	41.9
Green	25.3	42.7	24.0	40.7
Orange	18.7	32.1	21.0	35.8
Purple	50.0	76.6	14.5	25.0
Yellow	24.0	40.7	33.5	55.2

Critical difference between *alternate choice* × *colour* means (transformed values) = 21.4.

It is observed that when the alternate choice is 'ground glass' red and purple attract significantly more beetles than the other colours and in the case of blue it appears that the percentage attracted is approximately the same as ground glass, whereas the percentage attracted to the other colours was much less.

When the alternate choice, however is 'no light,' blue attracts significantly more beetles than purple. From Table X it will be seen that only 14.5 per cent of the beetles are attracted to purple.

The significant differences are as given above and following from this the order of importance from the point of view of attracting beetles is given in Table XI.

TABLE XI

Percentage attracted to colours when given the alternate choice of ground glass or no light

Order	*Against Ground Glass*		*Against No Colour*	
	Colour	*% Attracted*	*Colour*	*% Attracted*
1 ..	Purple	76.6	Blue	63.3
2 ..	Red	67.2	Yellow	55.2
3 ..	Blue	53.4	Neutral	41.9
4 ..	Neutral	46.6	Green	40.7
5 ..	Green	42.7	Orange	35.8
6 ..	Yellow	40.7	Red	35.0
7 ..	Orange	32.1	Purple	25.0

From the table it will be seen that when the alternate choice is ground glass, the purple and red attract beetles blue and neutral have no effect and the green, yellow and orange are inferior to "ground glass." When no colour is the alternate choice, blue appears to attract beetles whereas neutral, green, orange, red and purple are inferior to no colour and yellow has no effect.

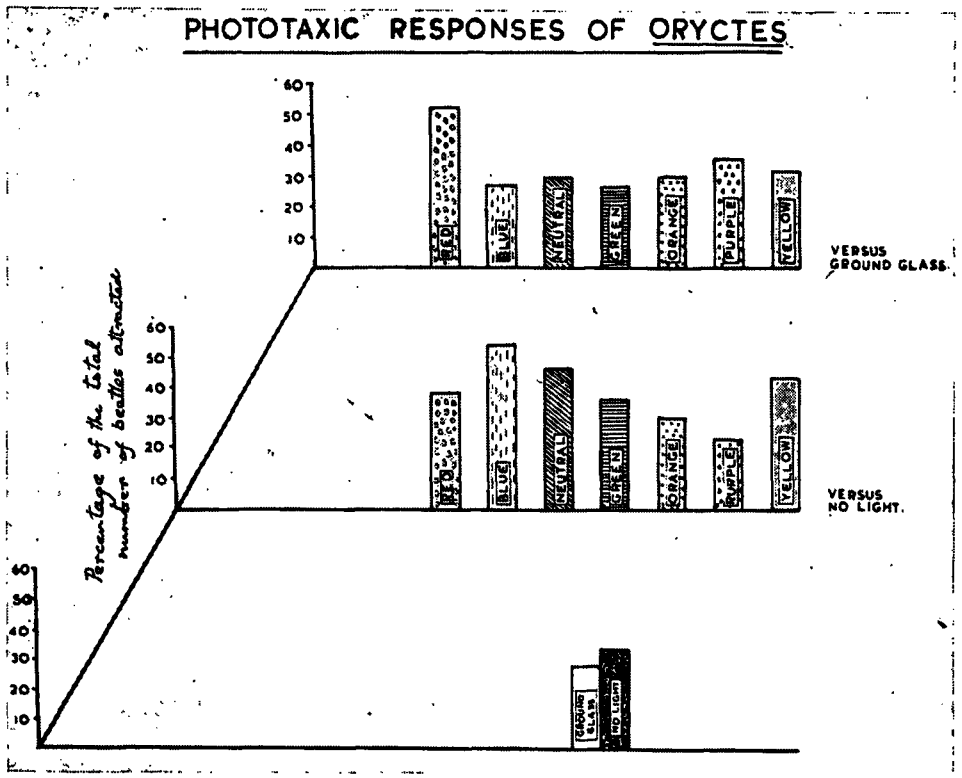

PLATE I

Comparative percentages of *Oryctes* attracted to various colours when given the alternate choice of ' colour ' versus ' ground glass ' or ' no light.' For purposes of comparison the values obtained for ' no light ' have been reduced in the same proportion as the ratio obtained for comparison ' colour ' versus ' ground glass ' *viz.* No light : ground glass is 1.2 : 1.

Discussion

It is known that *Oryctes* seldom fly during the brighter hours of day. Flight generally takes place at dusk or after. The beetles are also known to fly to lighted lamps. In the field, it has been observed that generally flight takes place mostly after dusk.

The stimulus for flight could be a feed stimulus as invariably one finds that initially flight takes place from the point of emergence to the food source which in most cases is the coconut palm. Flight could take place from one food source to another or from a food source to breeding material where copulation and oviposition occur. There is one record of the duration of flight and that is reported by O'Connor, B.A.

It has been observed by the senior author that in Ceylon emergence of adult *Oryctes* takes place with the advent of rains. Besides observations there is no data as to the predisposing factors of flight of *Oryctes viz.*, conditions which trigger the responses of flight. It is known that the newly formed adults can remain within their pupal case for a variable period. Our own finding in this respect is that it is from 17 to 22 days under laboratory conditions.

In these experiments we have tried to ascertain whether when beetle flights take place, which in all probability will be the result of the physiological condition of the beetle and the environmental conditions obtaining at the time, we are able, by the use of responses of beetles to light, to trap the beetles in flight.

The time of flight is an important consideration because of the fluctuation of the light intensity, at the time of flight. The light conditions which prevail at the time of flight are dusk and night fall. At dusk the light-intensities are low. In the experiment, the light emitted through ground glass is assumed to be identical with that which prevail at dusk, and the no light conditions with that which prevail at night fall.

If we consider the results obtained in the experiment on the face of this assumption then we see that if we are to trap beetles we will have to use two light sources — one type light source to trap beetles that fly before dusk and immediately after, another type of light source for beetles that fly when darkness prevails. The experiment has revealed that a red light source could be used to trap beetles that fly when day light conditions prevail, and a blue light source when conditions of darkness prevail.

This argument seems sound when we consider that flight from the natural breeding place results from a food response. The prime stimulus therefore is considered as an olfactory stimulus and it is during this stimulus that the phototaxic response is utilized for trapping *Oryctes*. The experiment does not indicate whether the phototaxic response would supersede the food response. However, when the food factor is not limited as in the experiment, then *Oryctes* do respond to phototaxic stimuli.

Summary

1. The analysis of variance for the main effects, *viz.*, colour, sex, alternate choice, shows no significance.
2. The interactions, colour × sex and alternate choice × sex show no significance.
3. The interaction alternate choice × colour is statistically significant. It is observed that when the alternate choice is ground glass the purple and red attract significantly more beetles than the other colours. When the alternate choice is no light, blue attracts significantly more than other colours.

   Besides red, purple, and blue the colours used are green, yellow, orange and neutral.
4. The findings are of economic importance, in that they could be used in light traps for trapping *Oryctes*. The findings suggest that a red light source should be used to trap beetles that fly before darkness sets in and a blue light source be used to trap beetles that fly after darkness sets in.

Acknowledgements

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References

(1) Goonewardene, H. F.—The Rhinoceros beetle (*Oryctes rhinoceros L*) in Ceylon, Part II A – Phototaxic responses of *Oryctes rhinoceros L.* – " White light " versus " Coloured light."

(2) Goonewardene, H. F. *et. al.*—The Rhinoceros beetle (*Oryctes rhinoceros L*) in Ceylon, Part II B – Phototaxic responses of *Oryctes rhinoceros L.* – " No light " versus " Coloured light."

(3) O'Connor, B.A.—The Rhinoceros beetle (*Oryctes rhinoceros L*) in Fiji. Fiji Agricultural Journal, Vol. 24, Nos. 1–2, September 1953.