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PHOTOTACTIC RESPONSE OF TWO SPOTTED CRICKET (*Gryllus bimaculatus De Geer*) TO ELECTRIC BULB LIGHT COLOURS AND TYPES

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ABSTRACT

This study examined the phototactic response of two spotted cricket (*G. bimaculatus*) to incandescent and LED bulb light of different colours. Light traps fitted with 25 Watts incandescent bulbs and 3 Watts Light Emitting Diode (LED) of different colours (red, yellow, green, blue and white) were used. Also included was a control trap. The traps were operated from 1800hr to 2400hr. *G. bimaculatus* collected were counted and the data subjected to variance analysis. Student Newman Keul's test was used to separate significantly different means at 5% level of probability. Relationship between light intensity and insect density was assessed by correlation and linear regression analysis. Results indicated that LED had higher mean intensity despite lower wattage and that, Blue colour had the highest mean intensity (736.80 Lux) among the LEDs and white (1094.20 Lux) among the incandescent bulbs. Statistical analysis showed that differences in attractiveness among LED bulb colours were due to random variation ($p = 0.17$); however was significant ($p < 0.001$) among incandescent bulbs. Of the total *G. bimaculatus* collected attracted, 93.7% was by LED bulbs with blue LED bulb alone attracting 57.1%. Light intensity was positively and significantly correlated with density of *G. bimaculatus* attracted for both LED ($r = 0.92$, $R^2 = 84.4\%$) and incandescent ($r = 0.96$, $R^2 = 92.5\%$) bulbs. Higher attraction of *G. bimaculatus* to blue coloured LED bulbs could be attributed to preference and/or high light intensity. Blue LED bulbs of higher intensity can thus be used to manipulate *G. bimaculatus* for man's benefit.

Contribution/Originality: The study is one of few that investigated the phototactic response of *G. bimaculatus* to electric light type and colours. This information is necessary in manipulating the insect's directional movement behaviour for the benefit of man.

1. INTRODUCTION

The phototactic response of some insects explains why they are often seen hovering around lit artificial light sources especially at night (Barghini & de Medeiros, 2010) thereby facilitating foraging, navigation and mate selection (Adeoye *et al.*, 2014) while also leading to the invasion of harmful species to inhabited areas (Barghini & de Medeiros, 2010).

Preferences to different light bulb colours and types have been studied in a number of insects (Pawson & Bader, 2014; Wakefield *et al.*, 2016; Nirmal *et al.*, 2017; Wakefield *et al.*, 2017; Chukwu *et al.*, 2019) with some findings showing that some electric bulb colours or types might pose a threat to the biodiversity of surrounding ecosystems due to their high attractiveness to a wide range of insect species (Eisenbeis & Erick, 2010).

The two-spotted cricket (*G. bimaculatus*) has been considered a nuisance in some part of the world where they periodically invade residential areas causing irritations especially by their chirpings. In some other places, the insect have been reported as pest of crops such as tobacco, corn, sunflower, cotton and, some fruits and vegetables (Ogbalu & Renner, 2015; Oso & Borisade, 2017).

On the other hand, the two-spotted cricket have been reported to be a better, more affordable and accessible source of animal protein which can be used in balancing the essential protein needs in humans and livestock including poultry, thereby reducing the risk of having individuals with such protein deficiency caused diseases or death and hence improving the health and productivity of both humans and livestock (Miech, 2018). Additionally, cricket farming is presently a trending agricultural practice in countries such as Thailand and Cambodia (Miech, 2018).

G. bimaculatus is also an important research specimen. For example, Seth & Cassandra (2016) reported that the insect has long been used as a model for behaviour, neurobiology, physiology and insect developmental genetics as well. Specifically, the two-spotted cricket have become models of speciation research and have been the subjects of prominent research programmes in speciation over the years (Gray *et al.*, 2016).

The rigors of controlling the insect in areas where they are pests and the means of harvesting it for food, agriculture, research, trade, among others have been shown to be costly, stressful and discouraging. Therefore, the objective of this study is to determine the preference of *G. bimaculatus* to LED and incandescent light colours for the purpose of recommending easier and cost effective means of manipulating the insect for the benefit of man.

2. MATERIALS AND METHODS

2.1. Study Site

The study was carried out in May, 2019 in the Research farm of Federal University Wukari, Taraba State, Nigeria. Wukari Local Government Area has an area of 4,308 square kilometres, lying in latitude of 7.89N and longitude 9.77E. It is a guinea savannah zone which has an average elevation of 189m, an annual average temperature of 26.8°C and an annual precipitation of 1,205mm (Okrikata & Yusuf, 2016).

2.2. Insect Trap Design

Light traps were fabricated using transparent white plastic sheetings (served as the screen), wooden frames/poles, 5 differently coloured (ECOMIN-QP05014/3W; AC220-240V/50-60Hz) light emitting diode (LED) bulbs (yellow, red, blue, green and white); same for incandescent bulbs (JUNGSRAM 25W; G45, 220V, E27, 1000h).

The bulbs were powered by Tiger-generator (TG950). The light intensity of each bulb was measured in a dark room using a digital Lux meter (Serial no.: 20111100416). White plastic sheeting was attached to two wooden frames at both sides to form a screen for the trap. A bulb was placed on top of each trap to reflect on the screen at a height of 1m above ground level. Each trap was placed at a 3m distance apart from each other to prevent masking effect by adjacent light colours Figure 1.

A 10 litre capacity bowl which was ¾ filled with water containing 2% liquid soap (which served as a wetting agent) was placed below each trap and used as the collection vessel. A total of six traps were made for each bulb type, of which five had the different coloured bulbs (LED and Incandescent) mentioned above hunged on the screen. A trap without bulb served as the control. Species attracted to the respective light colours and control, fell into the bowl on hitting the screen and were trapped. Traps were not set when there are signs of rainfall and collections were discarded any night it rained.

2.3. Insect Collection and Identification

The trap was set from 1800 hours to 2400 hours and the two-spotted crickets trapped by the different bulbs and colours were collected into different well-labelled sample bottles containing 70% ethanol for preservation and subsequent counting.

Sample specimens were sent to the insect museum of Institute of Agricultural Research (IAR) in Ahmadu Bello University, Zaria for confirmatory identification after conducting a preliminary morphological identification of the insects using both the insect microscope and hand lens in the Department of Biological Sciences laboratory of Federal University, Wukari.

2.4. Statistical Analysis

The count data were transformed using $\sqrt{x} + 0.5$ before variance analysis. Significantly different treatment means were separated by Student Newman Keul's test at 5% level of probability. Student's t-test (two-tailed) was used for comparing the attractiveness of LED and incandescent bulb colours to *G. bimaculatus*.

The relationship between intensity of light colours of each bulb type and density of *G. bimaculatus* attracted were determined by correlation and linear regression analyses. All analyses were done using IBM SPSS Statistics version 23.0 (SPSS Inc., Chicago, Illinois).

3. RESULTS

3.1. Light Intensities and Attractiveness of Bulb Light Colours to G. bimaculatus

The measured light intensities of the bulbs showed that Red, Yellow and White incandescent bulbs had higher intensities than their corresponding LED bulbs while, Green and Blue LED bulbs had higher intensities than their corresponding incandescent bulbs.

Overall, despite low wattage (3W) the LED bulbs had higher mean intensity (381.03 Lux) over the 25W incandescent bulbs (338.63 Lux) Table 1.

Among the LEDs, Blue followed by white bulbs attracted the highest proportion of *G. bimaculatus*; 57.1% and 21.3%, respectively while the least was Red LED bulb with 1.3% attraction. Table 1 also indicates that the blue LED bulb attracted the highest number of *G. bimaculatus* (4.07±1.67), and this was followed by white bulb (2.61±0.64) and green bulb (2.11±0.49). The control trap attracted the least mean number of *G. bimaculatus*. Variance analysis however showed that, the differences in *G. bimaculatus* attracted by LED bulbs were due to random variation ($p = 0.17$) Table 1. Among the incandescent bulbs however, Table 1 shows a significant difference ($p < 0.001$) in their attractiveness to *G. bimaculatus*. White colour attracted significantly the highest mean number of *G. bimaculatus* while the other bulb colours were statistically at par with the control trap which attracted the lowest mean number (0.71±0.00) alongside green and blue bulbs.

Table-1. Light intensities of LED and incandescent bulbs and their attractiveness to *G. bimaculatus*.

Bulb Colours	LED Bulb		Incandescent Bulb	
	Light intensity (Lux)	Mean Number of *G. bimaculatus* Attracted	Light intensity (Lux)	Mean Number of *G. bimaculatus* Attracted
Red	$60.18±5.97^{e}$	$0.86±0.15^{a}$	$65.36±3.55^{d}$	$0.86±0.15^{b}$
Yellow	$243.20±16.47^{d}$	$1.90±0.67^{a}$	$334.00±3.36^{b}$	$0.80±0.09^{b}$
Green	$513.80±27.00^{b}$	$2.11±0.49^{a}$	$154.20±4.24^{c}$	$0.71±0.00^{b}$
Blue	$736.80±13.02^{a}$	$4.07±1.67^{a}$	$45.40±1.57^{de}$	$0.71±0.00^{b}$
White	$351.20±4.31^{c}$	$2.61±0.64^{a}$	$1094.20±38.51^{a}$	$1.80±0.14^{a}$
Control	$0.00±0.00^{f}$	$0.71±0.00^{a}$	$0.00±0.00^{e}$	$0.71±0.00^{b}$
F-value	38.27	1.76	67.52	22.45
P-value	<0.001	0.17	<0.001	<0.001

Note: 1 - Means (±SE) followed by the same superscript letter(s) within a column are not significantly different using Student-Newman Keul's (SNK) test ($P \leq 0.05$).

Figure-1. Showing light traps setup [**Trap 1:** control, **Trap 2:** green, **Trap 3:** red, **Trap 4:** white, **Trap 5:** yellow and **Trap 6:** blue] spaced 3 m apart in the field (Traps are numbered from left to right).

3.2. Relative Attractiveness of LED and Incandescent Bulb Light Colours to G. bimaculatus

Table 2 shows that, across the bulb colours and the pooled mean, LED bulbs consistently attracted more *G. bimaculatus* than incandescent except, for red colour where both bulbs were at par (t-α = 0.00). Differences were however due to random variation except for green colour [LED (2.11±0.49); (0.71±0.00)] (t-α = 0.04).

Table-2. Comparison between LED and incandescent bulb colours on the attraction of *G. bimaculatus*.

Variable	Mean Count for LED	Mean Count for Incandescent	Mean Difference	*t-value*	*P-value*
Red	0.86±0.15	0.86±0.15	0.00±0.21	0.00	1.00
Yellow	1.90±0.67	0.80±0.09	1.10±0.67	1.64	0.16
Green	2.11±0.49	0.71±0.00	1.40±0.49	2.84	0.04
Blue	4.07±1.67	0.71±0.00	3.36±1.67	2.01	0.10
White	2.61±0.64	1.80±0.14	0.81±0.66	1.23	0.27
Pooled Mean	2.31±0.71	0.97±0.06	1.33±0.71	1.89	0.12

3.3. Relationship between Attractiveness of G. bimaculatus by Bulb Light Colours and their Intensities

Light intensity was positively and significantly correlated with *G. bimaculatus* density in both LED (r = 0.92, R^2 = 84.4%) and incandescent (r = 0.96, R^2 = 92.5%) with p-values of 0.01 and 0.04, respectively Table 3.

Table-3. Correlation analysis and linear regression between *G. bimaculatus* count and bulb light intensity.

Variable	Correlation Coefficient (r)	Regression Equation	Coefficient of Determination (R^2)
Insect count x LED Intensity	0.92^{**}	Y = 4.315 + 0.025x	0.844^{*}
Insect count x Incandescent Intensity	0.96^{*}	Y = 3.768 + 0.006x	0.925^{**}

Note: * = significantly different ($P \leq 0.05$).
** = significantly different ($P \leq 0.01$).
*** = significantly different ($P \leq 0.001$)
^{ns} = not significantly different ($P > 0.05$).

4. DISCUSSION

Different insects have preferences for different light bulb colours and types which could be attributed to the differences in wavelength/intensities of these respective colours (Nirmal *et al.*, 2017; Chukwu *et al.*, 2019; Okrikata *et al.*, 2020). Insect abundance including *G. bimaculatus* is known to be more in the tropics, but this abundance is not adequately harnessed for man's benefit. Blue colour has been reported by Cruz & Lindner (2011) as a region of maximum stimulation for majority of insects. This was apparently noticed in the current study with respect to LED. That white light was highly attractive to *G. bimaculatus* in the current study have been reported by Nirmal *et al.* (2017) and Miech (2018) with Miech (2018) pointing out that white light is being used in insect traps to harvest

G. bimaculatus in Cambodia and Thailand. Cumulatively, blue coloured LED bulb proved to be most attractive in the present study. This contrasts the finding of Chitra (2018) who found red coloured incandescent bulbs most attractive to orthopterans predominated by *G. bimaculatus*. The high attractiveness of *G. bimaculatus* to blue coloured LED is of interest as it can be harnessed for proper management of the species especially in the tropics where the species is abundant. In areas where *G. bimaculatus* are nuisance, reducing the use of blue LEDs as outdoor lights (as seen at night in some recreation centres) can effectively reduce the density of the attracted insect species thus saving the cost of pesticide and potential danger of exposure to some of the toxic chemical pesticides which are largely used for their management. Making insecticidal traps using blue coloured LED will be efficient in managing the species in areas where they occur as pests thereby providing a better, cost effective and environmentally friendly management strategy for the species. Additionally, the rigors of collecting *G. bimaculatus* for food, agriculture, scientific research, conservation and even export can be drastically reduced with the knowledge that blue coloured LED bulbs are effective attractants of the species. Hence, appropriate blue coloured LED insect traps can be used to effectively and efficiently harvest the species. LED bulbs have been reported to be insect friendly (Eisenbeis & Erick, 2010; Okrikata *et al.*, 2020), eco-friendly and energy saving (Wakefield *et al.*, 2017) and hardly emits ultraviolet radiations. It has also been observed that different bulb types attract insects at varying levels (Nirmal *et al.*, 2017; Ebadi *et al.*, 2018). Contrary to the findings of the current study, Barghini & de Medeiros (2012) and Wakefield *et al.* (2017) in their studies opined that LEDs are less attractive to many insect species than their incandescent, compact fluorescent and metallic halide counterparts as many insect species according to them, are disproportionately attracted to UV lights. However, even though the difference between LED and incandescent bulbs with respect to attractiveness to *G. bimaculatus* in the present study was due to random variation, that LED was more attractive than incandescent as observed in the present study, buttresses the findings of Pawson & Bader (2014) who showed that of Incandescent, Compact Fluorescent and LED bulbs; LED bulbs was most attractive to insects. In addition, even though Wakefield *et al.* (2017) reported higher insect attractiveness to halogen bulbs because of its emission of UV light in southern England, LED bulbs was reported by the authors to attract greater insect diversity than incandescent bulbs. In a study conducted by Nirmal *et al.* (2017) and Chitra (2018) they observed that irrespective of colours, incandescent bulbs were more attractive than compound fluorescent light with respect to orthopteran species. That incandescent bulbs were more attractive to fluorescent light in their study and LED to incandescent in the present study underscores the need to evaluate the responses of insects to different electric light types. Even though the LED bulbs used in the current study were of lower wattages (3W) compared to their incandescent counterparts (25W); overall, the LED bulbs had higher mean light intensity than the incandescent bulbs. This might be responsible for higher attraction of the insect species to the LED bulbs than to the incandescent bulbs, thus buttressing the report of Pawson & Bader (2014) and Chukwu *et al.* (2019) who opined that higher light intensity for LED bulbs relative to incandescent resulted to higher attractiveness of the insects to LEDs. Similarly, Wakefield *et al.* (2016) showed that higher attractiveness of insects to light sources was due to relatively higher light intensity. These, agrees with the current study which showed rising attraction of *G. bimaculatus* with increased light intensity. The effect of light intensity on the attraction of *G. bimaculatus* in this study was also observed among the incandescent bulbs in which white incandescent bulb which had the highest intensity resulted to higher attractiveness of the insect species. That LED bulbs are more efficient than incandescent bulbs in relation to light intensity as reported by Wakefield *et al.* (2017) was obvious in the current study where 3W LED bulbs produced higher light intensity than 25W incandescent bulbs. This apparently indicates that higher wattages of the LED bulbs will produce even higher light intensity which may result to higher attraction of *G. bimaculatus*.

5. CONCLUSION

Aside being an important source of protein for humans and livestock, the two spotted cricket (*G. bimaculatus*) is a key nocturnal Agricultural pest. This study has shown that *G. bimaculatus* are attracted to artificial light at night. It has also shown that the species are attracted predominantly to blue LED bulbs and that lights of higher intensities attract more of the species than lower intensity lights. It is therefore suggested that their attraction to bulb types and colours is due to the influence of colour and/or light intensity. Hence appropriate use of bulb colour and light intensity can be instrumental in manipulating the insect species for the benefit of man.

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