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Low Energy Trap with Light Emitting Diode for Increased Attraction of *Phthorimaea operculella Zeller*

Hipólito Carbajal-Morán[1*], Javier F. Márquez-Camarena[1], Carlos A. Galván-Maldonado[1], Rosa H. Zárate-Quiñones[2], Alberto C. Galván-Maldonado[3]

[1] Instituto de Investigación de Ciencias de Ingeniería, Facultad de Ingeniería Electrónica-Sistemas, Universidad Nacional de Huancavelica, Jr. La Mar 755, Pampas 09156, Huancavelica, Perú

[2] Facultad de Ciencias Forestales y del Ambiente, Universidad Nacional del Centro del Perú, Av. Mariscal Castilla N° 3909-4089, Huancayo 12006, Junín, Perú

[3] Facultad de Ingeniería, Universidad Nacional de Trujillo, VXM5+HVJ, Trujillo 13011, La Libertad, Perú

* Corresponding author's e-mail: hipolito.carbajal@unh.edu.pe

ABSTRACT

The *Phthorimaea operculella* Zeller moth is a pest that affects potato crops and is found mainly in the inter-Andean valleys of the highlands of Peru (Huancavelica). The objective of the research was to use the phenomenon of light generated by light-emitting diodes (LEDs) to attract the potato moth in storage. Every day at seven o'clock in the morning, the number of moths falling dead in the light trap on the water contained in the container was counted. Five LED lights with different light densities per square centimeter were tested for five nights with different frequencies: 3.125 Hz, 12.5 Hz, 50 Hz, 200 Hz and 400 Hz. Every five nights the operating current of the LEDs was changed: 5 mA, 10 mA and 15 mA. Every fifteen nights the color of the LEDs was changed, according to the following sequence: white, blue, green, yellow and red; the color that attracted the most was white light, while the one with the least attraction was red light. The white light trap using the 64 LED array attracted 38.73% of moths and consumed a total of 43 W of energy in seven days, so it is considered low energy consumption.

Keywords: LED array, light trap, moth, potato, oscillation with flashing.

INTRODUCTION

The potato *Solanum tuberosum* L. is a tuber belonging to the Solanaceae family and native to Central and South America (Campos & Ortiz, 2020). Potato is the world's third largest crop in terms of human consumption (FAOSTAT, 2019). Due to its versatility and adaptability to a wide range of environmental conditions, potato is now produced in approximately 150 countries in temperate, subtropical and tropical agroecologies, and stands out above many crops (Campos & Ortiz, 2020). Potato postharvest handling is an important determinant of uniform sprout growth and insect resistance. The common practice of continuing to use infested seed potatoes is the major cause of potato moth population growth (Adhikari et al., 2022) in storage facilities. Chemical pesticides cause non-target beneficial insects to become incapacitated and target insects to become resistant to pesticides (Álvarez Marroquín & Gutiérrez Rincón, 2020; Kroschel et al., 2020). The development of insecticide resistance by PTM combined with often insufficient means to monitor tuber moth populations usually results in excessive insecticide use (Okonya & Kroschel, 2015). Identification of appropriate biological options with biological justification could reduce reliance on toxic chemical insecticides.

Stored potatoes are affected by abiotic factors such as temperature, relative humidity and air quality during storage (Alamar et al., 2017; Foukaraki et al., 2014; Perez Melo, 2022) and biotic factors, especially insects and mites (Groves, 2010; Kroschel et al., 2020). *Phthorimaea operculella* Zeller known as the potato moth is an important oligophagous pest of solanaceous crops in many countries and regions. PopeOBP16 is one of the PBOs in potato moth (Li et al., 2023), in the Peruvian Andes it becomes economically relevant due to damage it causes at the storage level (SENASA, 2017). The adult female moths after interbreeding with the male deposit eggs on the tuber (Barreto-Triana et al., 2020), the larvae upon hatching enter the interior of the tuber, when feeding they produce galleries and fill with excrement, the mature larvae leave the tuber and pupate on the surface of the tuber or also on the surface of the soil, wall and/or any surface; the adults hatch and continue again the life cycle increasing exponentially the damage to the product (Gómez, 2021; Granados Ferrer, 2021). Control of the pest is increasingly difficult as it develops resistance to pesticides. Several entomopathogenic nematode species (EPN) have been reported to successfully control numerous agricultural pests worldwide (Barış et al., 2023).

The control of moths in potato stores in the Andes of Peru is generally based on the use of synthetic insecticides, mainly the following: carbaryl, chlorantraniliprole, malathion, pirimiphos-methyl, spinetoram and spinosad, although many of them are registered only for field populations of the pest; generating contamination in the product with toxic residues from these insecticides; therefore it is necessary to evaluate non-chemical control methods (Arcos Pineda et al., 2020; Larraín et al., 2009). Several non-chemical control studies have been developed to combat potato codling moth. Al-Ubaidy (2023) studied the development of the entomopathogenic fungus Metarhizium anisopliae by exposing to UV radiation type C whose wavelength was 254 nm having as irradiation periods of 10 and 15 minutes on potato moth pupae under laboratory conditions, the results showed that the irradiated fungi had a significant effect in decreasing the percentage of emergence with increasing concentrations, also showed a decrease in the proportion of blood proteins of 6. 30 and 8.14 μg/L to adults that emerged from pupae aged (1–2) and (6–8) days respectively. The use of silicon dioxide nanoparticles for the control of this type of pests is also possible (Idris et al., 2023). On the other hand, Kirisik et al. (2023) studied the trapping efficiencies of a newly designed light trap and a delta pheromone trap were comparatively evaluated in mass trapping of adult PTMs on stored potatoes during the storage period from October to December in 2019 and 2020 in Antalya province in Turkey; the results indicated that significantly more moths were captured per trap in the light trap rooms than in the pheromone trap plots so the tuber damage rate was relative to the moth capture. Because of the importance of eliminating potato moth, the research focused on implementation of light traps for potato moth elimination using LEDs.

MATERIALS AND METHODS

Five LED luminaires of different configurations were built: semi-spherical configuration of 64 LEDs (Fig. 1). Also, the hemispherical luminaire was configured with 32 LEDs, shown in Figure 2. Likewise, the 32 LED square luminaire was configured and is shown in Figure 3. In the triangular luminaire configuration, 24 LEDs were used which is shown in Figure 4.

Finally, the luminaire was configured as a cross or cross-like luminaire with 16 LEDs (Fig. 5). Each LED configuration had a different density distribution; Table 1 shows that the hemisphere in Figure 1 has the highest density (1.3061 LEDs/cm^2), while the cross configuration has the lowest density (0.1975 LEDs/cm^2). The various

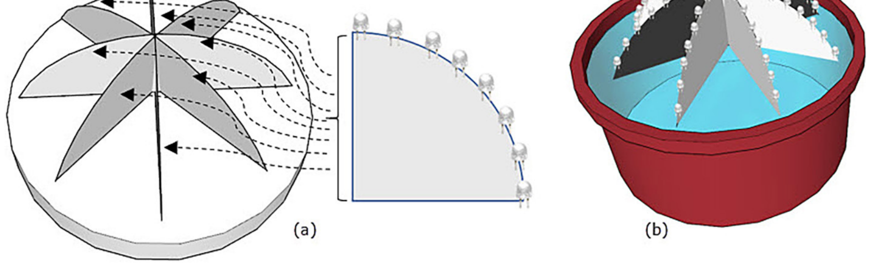

Figure 1. 64-LED hemispherical configuration: (a) LED positioning and (b) location above the water

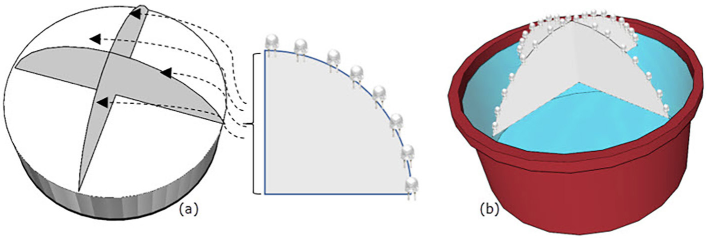

Figure 2. Semi-spherical configuration of 32 LEDs: (a) positioning of the LEDs and (b) location above the water

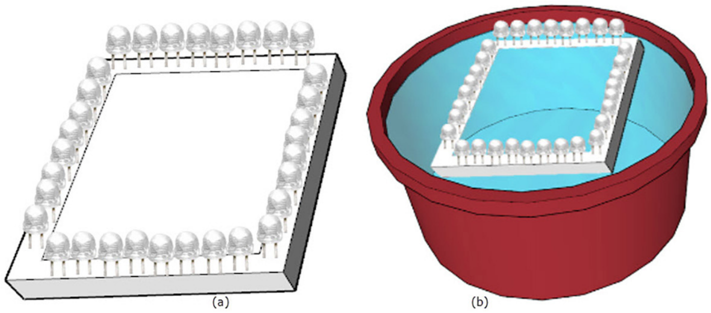

Figure 3. 32 LED square configuration: (a) LED positioning and (b) location above the water

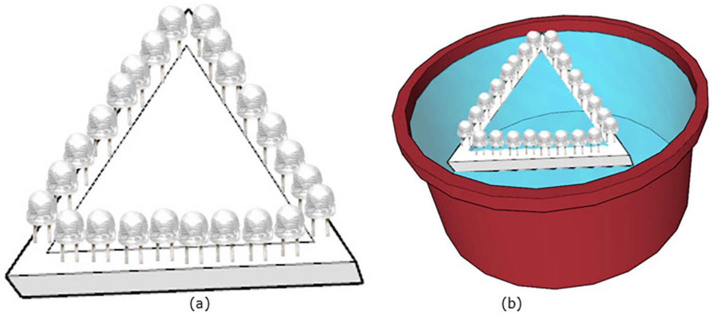

Figure 4. 24-LED triangle configuration: (a) positioning of the LEDs and (b) location above the water

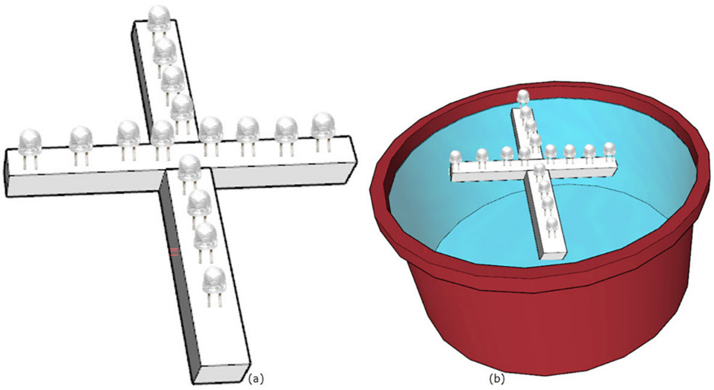

Figure 5. 16-LED cross configuration: (a) positioning of the LEDs and b) location on the water

configurations were activated intermittently in arrays of 8 (see Fig. 6) by frequencies of 3.125 Hz, 12.5 Hz, 50 Hz, 200 Hz and 400 Hz. The switching current required for LED luminescence was provided by the 2N2222 transistor. The various configurations of LEDs placed over the container with water represent light traps, these were constructed by fastening on the outside of a plastic

Table 1. Summary of the relationship between number of LEDs and approximate area of each configuration

Configuration		Number LEDs	Area (cm^2)	Density (LEDs/cm^2)
1	Semisphere	64	49	1.3061
2	Semisphere	32	49	0.6531
3	Square	32	81	0.3951
4	Triangle	24	81	0.2963
5	Cross	16	81	0.1975

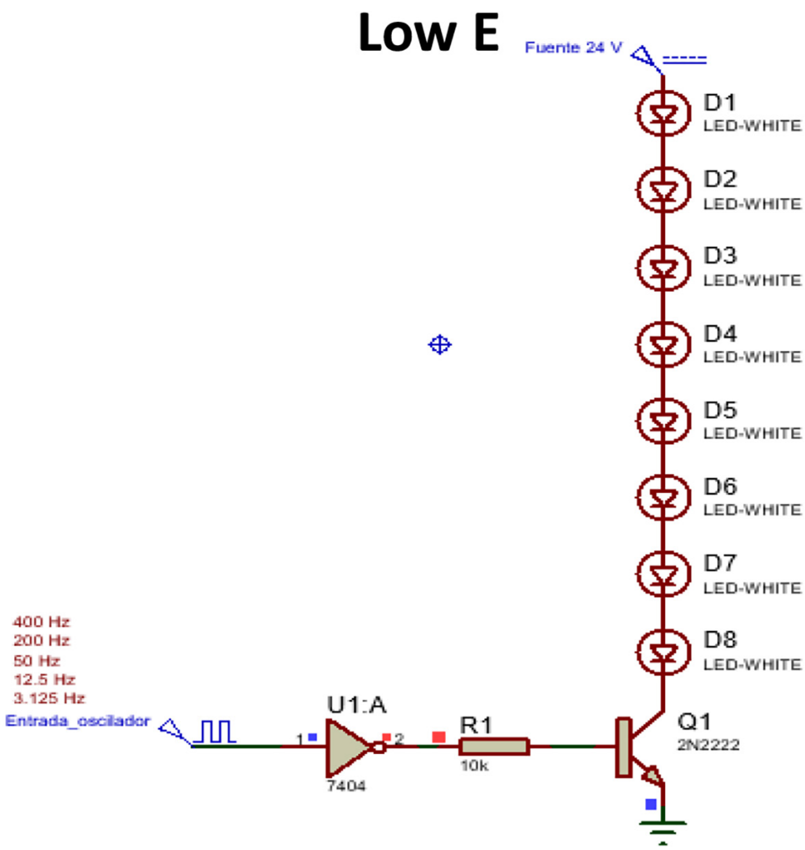

Figure 6. Switching and luminescence control circuit of the different LED configurations

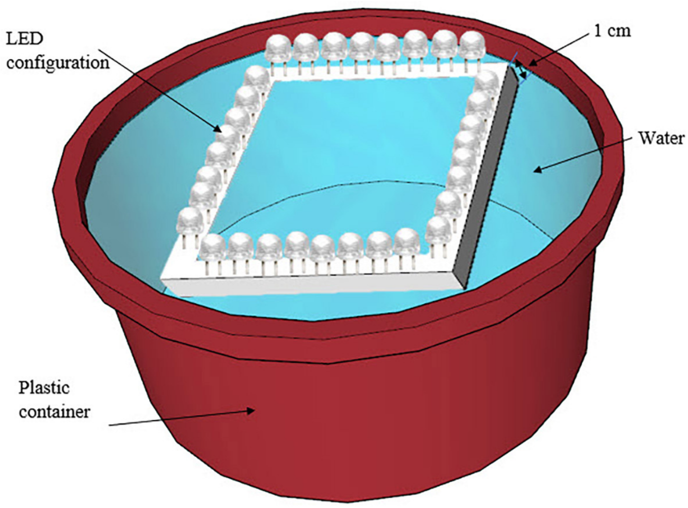

Figure 7. Light trap with LEDs at 1 cm from the water

Table 2. Moths attracted in 7 days by the different LED configurations and their respective energy consumption

Configuration	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Total (moths)	Average moths in 7 days	Power consumed (W)
Semisphere of 64 LEDs	10	10	8	8	7	6	6	55	7.86	43.01
Semi-sphere of 32 LEDs	8	6	6	5	5	4	2	36	5.14	21.50
32 LED square	7	6	5	5	4	4	1	32	4.57	21.50
24 LED triangle	4	2	1	1	1	2	1	12	1.71	16.13
16 LED cross or blade	2	2	1	1	1	0	0	7	1.00	10.75

tub using packing tape that holds the copper conductors coated with insulator, on these were fixed each of the LED configurations as luminaires; water was filled up to one centimeter below the luminaires.

RESULTS AND DISCUSSION

Performed the tests during 07 days of the week from Monday to Sunday with LEDs that generate white light, it is observed in Table 2 of the total number of potato moths trapped in the environment in the established days: the hemispherical configuration of 64 LEDs attracted more moths to the light trap; being this 38.73% of the total, the hemispherical configuration of 32 LEDs attracted 25.35%, the square configuration of 32 LEDs attracted 22.54%, the triangular configuration of 24 LEDs attracted 8.45% and the configuration that attracted the least moths was cross or cross with only 4.93%. The energy consumption is proportional to the number of LEDs flashed at frequencies of 3.125 Hz, 12.5 Hz, 50 Hz, 200 Hz and 400 Hz.

When evaluating the total number of moths for the different LED configurations, it is evident that the higher the luminosity, the higher the attraction of the moths to the light trap.

CONCLUSIONS

The power consumption of the different LED configurations was optimized by a flash frequency generator 3.125 Hz, 12.5 Hz, 50 Hz, 200 Hz and 400 Hz; so, the highest power consumption reaches 43 W in total for the 07 days of experiment, likewise, the light trap using the 64 LED array generated higher illumination and consequently attracted potato moths to the light trap by 38.73%, the hemispherical configuration of 32 LEDs attracted 25.35%, the square configuration of 32 LEDs attracted 22.54%, the triangular configuration of 24 LEDs attracted 8.45% and the configuration that attracted the least number of moths was the cross with only 4.93%. These types of potato moth traps are ecologically viable and economical.

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