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Improving light-trap efficiency for *Culicoides* spp. with light-emitting diodes

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Summary

The robustness of light traps used to monitor *Culicoides* spp. throughout Australia was improved with stainless steel and heavy duty plastic fittings. Printed circuit boards and light-dependent resistors were modified to be compatible with recent advances in electronics. In experiments with light-emitting diodes (LEDs), *C. brevitarsis* Kieffer was significantly attracted to green light. This species is the major vector of Akabane and bluetongue viruses in Australia and is the main target of a national monitoring programme using light traps. This response was significantly greater than the response to the incandescent lights currently used in the light traps. Catches of *C. brevitarsis* were also related to the intensity of the green LEDs. These were more effective than the currently used incandescent globes at intensities between 46% and 142% of the incandescent intensity. The response of seven other *Culicoides* spp. to the LEDs was also determined.

Keywords

Arbovirus monitoring – Australia – Bluetongue – *Culicoides brevitarsis* – Light-emitting diodes – Light intensity – Light trap – Vectors – Viruses.

Introduction

The Australian *Culicoides* fauna is extensive and diverse. Distributions are restricted by geography, weather and habitat availability. Several species from the genus are vectors of viruses affecting native animals (10). *Culicoides brevitarsis* Kieffer is the main species responsible for the transmission of bluetongue (BT) and Akabane viruses to livestock (9). Distribution is chiefly coastal and it is endemic in the eastern half of Australia from the Northern Territory (8) to the northern/mid-northern coastal plains of New South Wales (NSW) (2, 3).

Light traps with incandescent globes are used to monitor the presence of *Culicoides* species (as part of the National Arbovirus Monitoring Program [NAMP]) (7), to compare their relative abundances and to conduct research (2). Until recently, these traps had changed little from those first described by Dyce *et al.* (6). In the field, the traps are subjected to rough treatment and breakages were common and disruptive to the monitoring programme. Original printed circuit boards (PCBs) proved incapable of maintaining consistent outputs as new electronic technology developed. Replacement component (transistor) burnout increased as there was no definite switch point in the old system. This caused the transistors to half-switch and to dissipate more heat energy than could be tolerated. Improvements to the robustness and circuitry of traps were therefore major requirements for maintaining an efficient trapping system.

There have been instances at the margins of the distribution of *C. brevitarsis* in NSW where virus activity has been detected by the serological testing of sentinel cattle herds in the apparent absence of *C. brevitarsis* in light traps (P.D. Kirkland, personal communication). It was considered possible that the traps failed to record low numbers of infective *C. brevitarsis* and that trap efficiency should be reconsidered. Improved trapping of mosquitoes has been achieved by determining mosquito responses to the colour and intensity of light sources (1, 5). There have been no similar studies on *Culicoides* spp. Insects can generally perceive and respond to light in the 350-700 nm range and their relative response can vary considerably over this range. The standard incandescent light sources used in these light traps generally have a maximum output at 700 nm with little or no output below 400 nm. Advances in light-

emitting diodes (LEDs) in the last 5 to 10 years have produced LEDs that are energy efficient, often producing a greater total photon flux (TPF) than incandescent globes in the 400-700 nm range for the same power input making them suitable for battery operation such as that used in light traps. LEDs also can provide closely defined outputs across narrow spectral ranges enabling responses to colour to be investigated more effectively. A study was therefore conducted to determine the response of a range of Australian species of *Culicoides* to different colours in the visible spectrum with the use of LEDs.

Materials and methods

Modifications to light traps

Strengthening of the traps and changes to electronic circuitry were made progressively by trial and error over several years.

Light-emitting diodes

All experiments were conducted in the Hunter Valley (NSW) in 2002 and 2003.

The light source (incandescent globe) in standard light traps was replaced in treatment traps with a range of LED treatments and compared to the incandescent light. The traps were powered by three 1.5 V alkaline 'D' cells, which were replaced after two nights of operation. The quantum output of incandescent globes was measured at 20°C with a LI-COR Model LI-250 light meter with a LI-COR quantum sensor (approximately linear over 400-700 nm). The current to the LEDs (three for blue, green, white and red, and five for yellow) was then adjusted until the quantum output was the same as the incandescent light source. The LEDs (other than yellow) were mounted in polycarbonate plastic diffusers (120° apart) to ensure an even distribution of light. The yellow LEDs were mounted facing directly outwards on the same plastic caps at 72° apart as five were necessary due to their lower quantum output per current input compared to other LEDS used. Three trials were conducted.

The first trial was carried out in March and April 2002 using blue, green, white, yellow and red LEDs and the standard incandescent globes. The traps were hung from 2 m-high 'L' shaped frames placed at 20 m intervals on one side of ≈30 ha paddocks containing cattle. Yellow was not included in the first two experiments and replaced red in the next two experiments. The five treatments were arranged in five randomised blocks and re-randomised between each of four experiments. Collections were made over two nights into bottles containing 70% alcohol. *C. brevitarsis* was identified under ×10 magnification and total numbers were recorded.

The second trial was conducted in February 2003. The experimental site was chosen because it frequently has the greatest diversity of species at sites monitored in coastal NSW (A.L. Bishop, unpublished data). It is also marginal for *C. brevitarsis* in most years. Blue, green, yellow, red and incandescent treatments were used in this trial. The treatments were arranged in five randomised blocks which were re-randomised at the start of each of four experiments. Traps were hung as before at 12 m intervals on two sides of a ≈10 ha paddock containing cattle. Collections were made over one night, the samples sorted and numbers of *C. brevitarsis*, *C. austropalpalis* Lee and Reye, *C. bundyensis* Lee and Reye, *C. bunrooensis* Lee and Reye, *C. dycei* Lee and Reye, *C. marksi* Lee and Reye, *C. nattaiensis* Lee and Reye and *C. victoriae* Macfie recorded.

The third trial was also conducted in February 2003. Green LEDs at four intensities relative to the intensity of incandescent globes were compared with the incandescent light against *C. brevitarsis*. The intensities were varied by adjusting the current to the LEDs. The five treatments were arranged in five randomised blocks in a 36 ha paddock containing cattle. The treatments were re-randomised between each of four experiments. Collections were made over one night and *C. brevitarsis* numbers counted as before.

Statistical methods

The influence of light frequency or intensity on counts of *Culicoides* spp. was modelled using a mixed linear regression approach which allowed the separation of variance components into fixed and random effects. Insect counts were $\log_e$ transformed for Trial 1, Trial 3 and for *C. austropalpalis* in Trial 2. A square root transformation was used for counts of all other species in Trial 2 due to their low numbers. Analysis of the transformed counts was conducted using the restricted maximum likelihood (REML) directive in Genstat 5.4.1, Release 3. Treatment effects were examined for significance using Wald tests while treatment means were compared using the least significant difference (LSD) technique at the 5% level. In Trial 2, the counts for *C. brevitarsis* and *C. nattiensis* were very low and were subsequently pooled for each block and an analysis of variance performed.

Results

Modifications to light traps

The robustness of the light traps was improved by the addition of:

- heavy-duty PVC battery boxes and light-dependent resistor (LDR) covers
- stainless steel weather protection plates, ribs on cones and bottle connections.

The PCB design was modified by the additions of:

- screw terminals to prevent wire breakage
- a 10 turn 10 K trim pot to allow easy adjustments
- a definite 100% switch point to eliminate half switching
- a timer chip incorporating a hysteresis loop so that the light level required to switch the unit off would be higher than the level required to switch the unit on.

Light-emitting diodes

The treatment effect in Trial 1 was highly significant with catches of *C. brevitarsis* highest with green LEDs and with significant differences between each single-band treatment (Table I). White was similar to the blue and green treatments but included all wavelengths with peak emissions in the blue and yellow ranges.

Significant treatment effects were recorded in Trial 2 for each of the eight species recorded. Catches of *C. brevitarsis* were again highest with the green LEDs (Table I). *C. austropalpalis*, *C. bunrooensis* and *C. marksi* each exhibited highest responses to blue LEDs although green LEDs were also more effective than the incandescent light. Significantly higher responses to the blue and green LEDs relative to the incandescent could not be separated for *C. bundyensis*, *C. dycei*, *C. nattaiensis* and *C. victoriae*.

The overall treatment effect of different intensities of green LEDs was significant in Trial 3. Catches increased with intensity but were not significantly different at the two highest intensities (Table I). Significantly more *C. brevitarsis* were caught at all intensities tested than in the incandescent traps.

Discussion

Changes to the structure and circuitry of the light traps have significantly reduced trap breakage and breakdown and improved the efficiency of the NAMP. Light trapping of *C. brevitarsis* was more efficient when incandescent globes were replaced with green LEDs. Attraction was also more effective as the intensity of the green light was increased, with catches at four intensities significantly greater than those with the incandescent light. An upper threshold of intensity suggested by the two highest intensities require confirmation. While trapping of *C. brevitarsis* was the major aim, trapping of several other species would also be improved with the green LEDs. Specific trapping of some of these species could be maximised with blue LEDs.

Most predictions of the activity and spread of *C. brevitarsis* in NSW are based on population monitoring with light traps and are more dependent on the species occurrence than its density (2, 4).

Table I
Predicted (back-transformed) means of *Culicoides brevitarsis* in response to coloured light-emitting diodes arranged in spectral order in two trials and to different intensities of green LEDs in relation to the intensity of standard incandescent globes in Australia in 2002 and 2003

Treatment	LED experiments		LED intensity experiment	
	*C. brevitarsis**	*C. brevitarsis***	LED: incandescent TFD ratio (%)	*C. brevitarsis*
Red LED	17.0[c]	0	46	152.4[c]
Yellow LED	53.5[d]	0.7[b]	96	208.4[b]
Green LED	279.5[a]	4.7[a]	115	301.1[a]
Blue LED	173.5[b]	1.3[b]	142	326.3[a]
Incandescent	104.8[c]	0.5[b]	100 (incandescent)	115.1[d]
White LED	206.2[a b]			

* Trial 1 TFD total photon flux

** Trial 2 LED light-emitting diode

Means in columns with the same superscript letter are not significantly different (P <0.05)

Larger catches in endemic or established areas where the occurrence of *C. brevitarsis* is not in question may therefore be of little value and the extra time taken to count increased numbers be unnecessary. Greatest

benefit for monitoring use would be for first occurrences outside endemic areas and at sites with low *C. brevitarsis* density.

Further benefits could be derived where larger catches may be required for virus isolation from vectors, for experimental use of vectors with animals or for detecting vectors at key locations involved in the export of livestock (staging areas and ports). Colours with higher attraction could possibly be used in trapping systems designed to control the insects particularly where important livestock are kept in confined areas.

Other *Culicoides* vectors of the Akabane and bluetongue viruses also exist in Australia's far north. Determination of responses to colour in a wider range of *Culicoides* species throughout Australia and overseas could therefore be an important adjunct to the understanding and control of these pest species and this could easily be carried out with LEDs in currently used light traps.

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