A false colour analysis: An image processing approach to distinguish between dead and living pupae of the bagworms, *Metisa plana* Walker (Lepidoptera: Psychidae)

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ABSTRACT The bagworm is one of the main species of vicious leaf eating insect pest threats to the oil palm plantations in Malaysia. The economic impact from a moderate bagworm attack of 10%-50% leaf damage may cause 43% yield loss. Without any control actions, the bagworm population often increases to above its threshold limits, subsequently attributed to a severe outbreak. Realizing the impact, identification and detection of bagworm populations at the pupal stage are required as preliminary steps to ensure proper planning of control actions in the infested areas. Through a false colour analysis, a colour filter absorbed the unwanted colour wavelengths, which attributed to each pixel was specified to a certain colour wavelength. Distinct differences in the pixel count based on the slopes were observed for dead and live pupae at 630nm and 940nm, with the slopes being recorded at 0.38 and 0.28, respectively. The lower slope value indicated the living pupae and the higher slope value, represented the dead pupae. Hence, the analysis for distinguishing between the living and dead pupae of *Metisa plana* Walker, a species of Malaysia's local bagworm using RGB images is proposed for automated classification.

KEYWORDS: Bagworms; false colour; pixel count' slope, image sensor
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INTRODUCTION

The bagworm is a leaf-eating insect pest that attacks oil palm plantations in Malaysia. It has three major species, namely the *Mahasena corbettii*, *Metisa plana,* and *Pteroma pendula*. In this study, *M. plana* Walker was selected due to its life cycle characterisation and active spreading in Peninsular Malaysia, compared to other species. To control *M. plana*, especially at the pupal stage, the most frequent and practical way is by pheromone trapping using the receptive female of the pupa. Receptivity of the female was determined by the opening of the anterior end of the pupae bag plus the intermittent protrusion of the female's head and thorax from this opening (Basri & Kevan, 1995; Norman & Othman, 2006). The female stayed receptive for about nine days and closed the anterior end of the pupae bag after this period (Najib *et al*., 2017). In order to search for the living pupae, the normal practice is applied via census using the naked-eye vision which may cause fatigue and error to the field workers.

In the normal camera application, such as See3Cam_CU135 camera, a visible light image is considered 'true colour' as the camera sensor captures the information within the human visible light spectrum only, which falls within 400nm to 700nm, and it discards other light source information. This is achieved by the application of an infrared (IR) colour filter prior to the image sensor capture. If this filter is removed, the human can see the additional colour information from the captured image. This image is considered 'false colour' since the additional colour information is actually unseen by the human vision (Colantonio *et al*., 2007; Ciftci *et al*., 2017). Therefore, to extract colour information from a ‘false colour’ image, this study has been carried out to measure the average pixel count from the image and further analysis was also explored.

Realizing the importance of collecting and sampling the pupae, a false colour approach was introduced using true colour and RGB images of the pupae. This method was related to the spectral reflectance data of the pupae using the spectroscopy technique. From this data, the slopes of the dead and living pupae were found to be significantly different at certain wavelengths under the Visible/IR range. Referring to this data, a false colour analysis was introduced by observing the Vis/IR wavelengths, specifically at 630nm and 940nm. The bagworm images were captured under red and IR light sources, and the average number of pixels was counted under greyscale and then plotted. Linear slopes for both the dead and the living pupae were calculated to distinguish between both pupae. In this study, the false colour was used and assisted researchers and scientists in detecting the pupae, and they integrated the technique into the software that was located on a hardware platform. It has also been categorized as part of the machine vision approach for the development of the intelligence device in the agricultural industry.

METHODOLOGY

Test method

Two light sources have been identified to be economic and practical, which are the 940 nm (IR) and 630 nm (red). These two wavelength points were selected based on the spectral reflectance properties of the living and dead pupae, which was significantly different between the 630 nm to 940 nm. The data was achieved using a spectroradiometer to find the reflectance percentage at the specific wavelength for the pupae. As shown in Figure 1, the photodiode responsivity differed massively for the 630nm (red) and 940nm (IR) wavelengths. It was impossible to adjust the spectral efficiency of the AR1335. One way of normalising the different responsivity was by introducing a normalised power of the light source that matched the responsivity profile. Spectral efficiency was a profile that indicated image sensor responsivity towards light and it was shown in Figure 1. Note that this sensor was capable of detecting any light sources, with wavelength ranged from 400nm to 1090nm. However, to produce visible or RGB (red, green &blue) light image, only light between 400nm to 700nm was useful. The curve of red, green and blue representing the most responsive wavelength of the visible light with specific percentage of quantum efficiency. In this study, two wavelength points were picked up and compared with the responsivity profile. Therefore, IR-cut filter was introduced before the sensor to filter IR element which appear above 700nm. With IR-cut filter present, a ‘true colour’ image was produced by the sensor and without IR-cut filter present, a ‘false colour’ image was generated.

Calibration was conducted by setting up the camera and light source, whereby, the surroundings were covered to block light from outside, the height was maintained at 30 cm, the ground was set with white canvas, and the camera exposure was set to manual control. Other camera settings used the default parameters from the manufacturer.

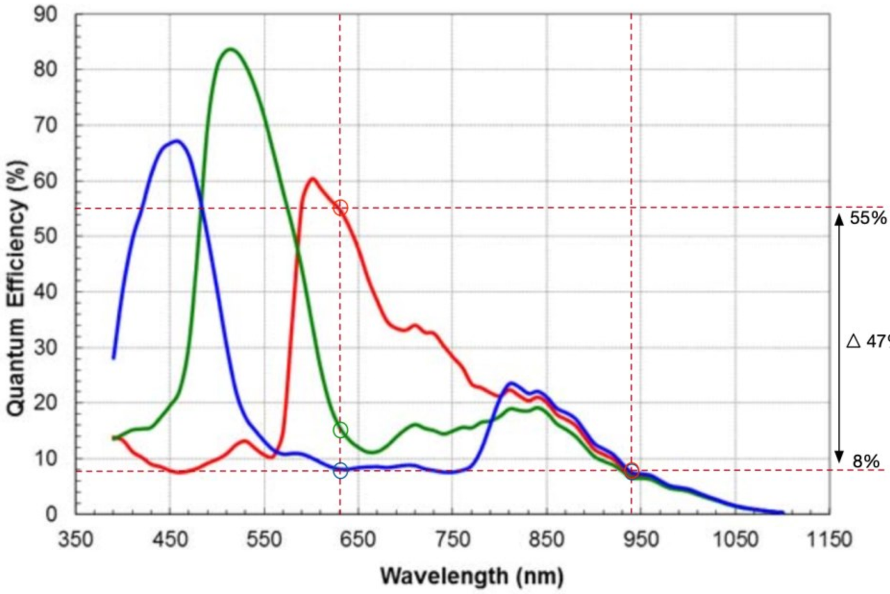

Figure 1. Different responsivity of the AR1335 sensor for the 630nm and 940nm wavelength (Ciftci *et al*., 2017)

The supply current for the light source was adjusted to be exactly at 255 for the most responsive pixels by using the OpenCV in greyscale image. The light source was set at the optimum level to avoid the possibility of the photodiode to excite more electrons than the maximum level. From the calibration, the voltage and current for both the 630nm and 940nm were found to be set at 10V 0.08A and 5V 0.13A, respectively.

The image analysis was simplified and more accurate when all pixels were represented by a single greyscale value using the equation: grey=0.299R+0.587G+0.114B (Ciftci *et al.*, 2017). This equation changed the pixel's interpolated RGB value back to the original pixels with no effect of the Bayer filter.

Experimental set up

60 samples of dead and 60 samples of living pupae were randomly placed on a black ground canvas. The rest of the other settings were maintained as explained above. Images for 630nm and 940nm were then captured in the RGB format by using bandpass filters. The bandpass filter allows light within the wavelength of a defined band to pass through the filter and block all other wavelengths. The images were converted to greyscale before an average of 30 pixel values were randomly picked within a pupa's boundary. Average pixel values were collected for all the samples.

Calculating the average pixel count

The steps for pixel counting are mentioned as follows:

1. Source captured in RGB.
2. Location of each pupa was marked, to calculate the slope value compared to the IR (940nm) of the pupa at the same location.
3. Viewed image in greyscale using the OpenCV imshow (img, imgfile, greyscale_option).
4. Zoomed each pupa until the pixel value was displayed.
5. Picked all pixels of pupae images.
6. Averaged the pixel value.

RESULT AND DISCUSSION

From the results, distinct differences in the pixel counts based on the slopes were observed for the dead and live pupae at 630nm and 940nm, following the spectral reflectance properties' trend, with the slopes recorded at 0.37 and 0.26, respectively. A positive result to distinguish between the living and dead pupae was achieved by using the image processing approach. This result was following the trend of the spectral reflectance data with slightly different slope values as shown in Table 1. It is recommended that live samples be collected and the image be instantly captured in the field.

Table 1. Measured slopes on reflectance of living and dead specimens using 630nm and 940nm wavelengths.

Descriptive statistics	Spectral reflectance		False colour imaging	
	Live	**Dead**	**Live**	**Dead**
Mean	0.26	0.38	0.26	0.37
Min	0.26	0.38	0.14	0.30
Max	0.27	0.38	0.29	0.50

From Figure 2, it is indicated that there was a significantly different slope value between the living and dead pupae. This result is supported by the means separation by the Students t-Test at $p<0.05$. However, in the image perspective (Figure 3), the red light source gave a clearer and more obvious difference of the dead and living pupae in visible imagery, as compared to the infrared (IR). According to Colantonio, *et al*. (2007), the IR vision is a vital support when facing low-lighting conditions or in case the target has a similar colour to the background. The visible imagery has a higher resolution and is able to display more detailed features, such as a target's geometry and localisation to discriminate the background. Further analysis by pixel counting under greyscale images resulted in different slope value for both pupae, which successfully gave a positive result in this study

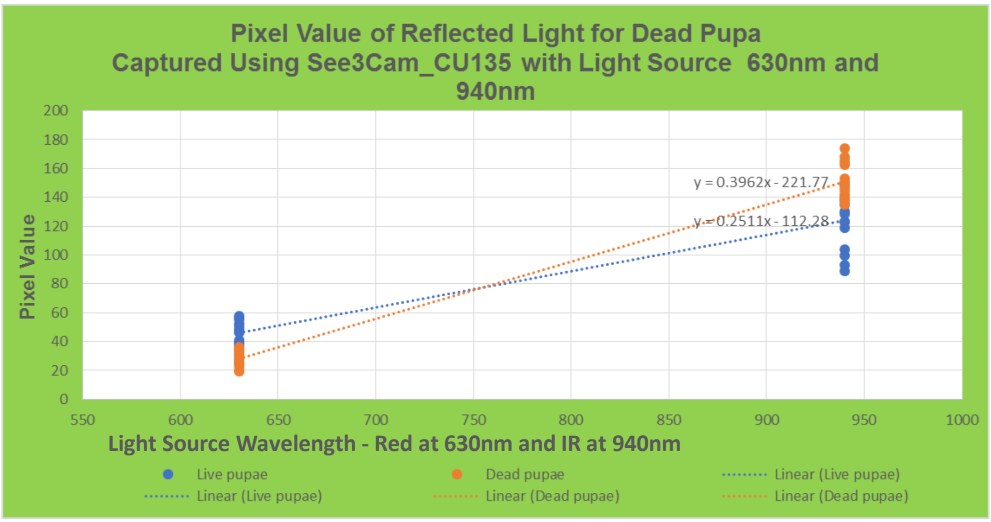

Figure 2. Observation of the pixel values of the greyscale image using the See3Cam_CU135 camera using two different light sources at 630nm and 940nm

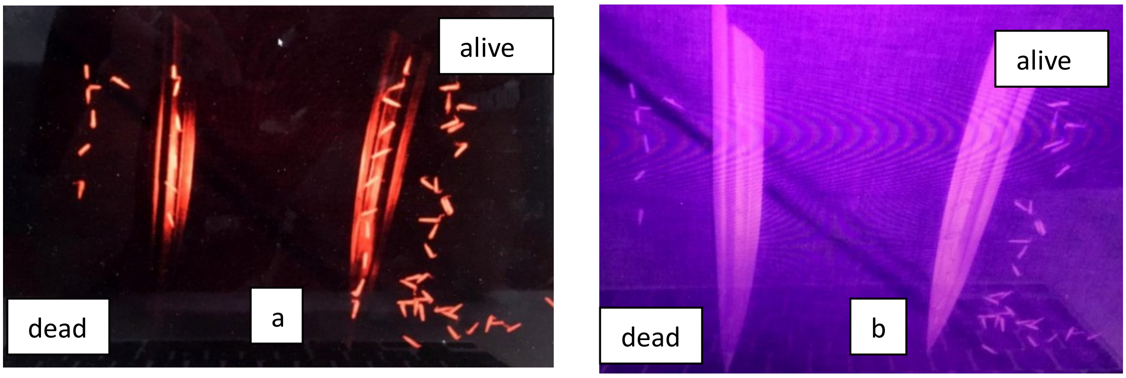

Figure 3. The dead and living pupae images captured under red, 630 nm (a) and infrared, 940 nm (b) light sources

A field test was conducted at the Slim River estate, Perak to test the detection accuracy for open (without) and with bandpass filter applications (Figure 4). The result shows that an 80% detection of live pupae was recorded by using the bandpass filters and 7% detection accuracy was logged through the open or without bandpass filter application.

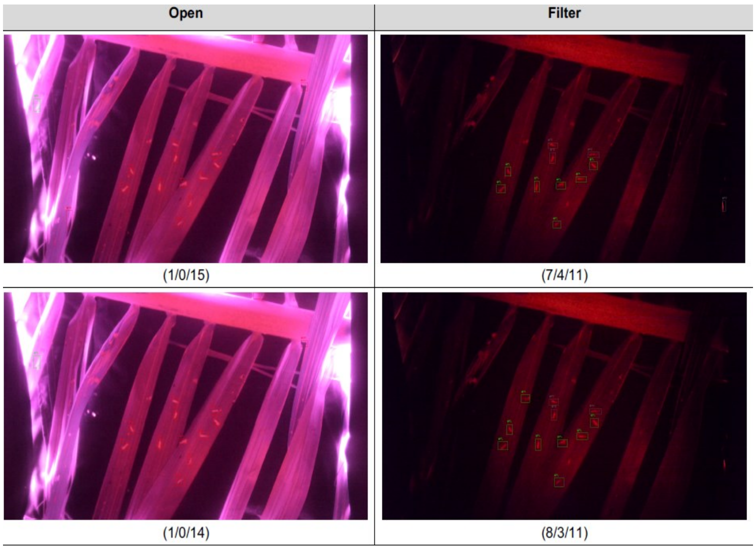

Figure 4. Infested palm leaflet images captured under a red light source using bandpass filters and without bandpass filters (open).

CONCLUSION

It has been revealed that the false colour approach is successful at obtaining positive results to distinguish between the living and dead pupae, with an average pixel counting and slope differentiation concept. The slope value ranged from 0.2-0.29 for the living pupae and 0.3-0.4 for the dead pupae. This technique is categorized as a crucial finding in the image processing scope and has been integrated with the Entomology field to detect and distinguish between the living and dead pupae of the bagworms, *M. plana* Walker.

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