Computer-based Image Analysis to Estimate the Area of a Sticky Trap Occupied or Contaminated by Pests

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Abstract

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Traps are tools frequently used to monitor and control pests. Therefore, it is important to study the prerequisites of their use. The instant active area of a trap (the instantly available area of a trap that is able to capture a pest) is a determinant of trap efficacy. However, to measure the instant active trap area is difficult. Therefore, we developed a technique of computer image analysis of digital photography to evaluate the instant active trap area, occupancy (area of insect bodies captured on the trap) and contamination (area of filth left by pests on the trap, such as wing-scales or faeces) of it. This study illustrates its use with two types of sticky traps applied to monitor the German cockroach, *Blattella germanica*, and the Mediterranean flour moth, *Ephestia kuehniella*. We found that moths decreased the capacity of the sticky surface more than cockroaches because of its contamination by wing-scales. The sticky trap area covered by wing-scales was nearly as large as the area occupied by moth bodies. Cockroaches contaminated the sticky surface by their faeces but the contaminated area was less than 2% of the area occupied by cockroach bodies. The results indicate that moths are heavy contaminators while cockroaches are weak contaminators of sticky traps.

Keywords: monitoring; traps; digital image analysis; *Ephestia kuehniella*; *Blattella germanica*

Monitoring is a keystone of Integrated Pest Management (IMP) in orchards, glasshouses, forestry, field crops or stored, urban and food industry environment (e.g. Stejskal 1993; Hagstrum & Subramanyam 2000; Campbell *et al*. 2002; Schal & Hamilton 1990). Although there are many methods of pest monitoring, currently the trapping method is the most frequently used. In addition, some pest control strategies (e.g. "mass-trapping" or "trapping-out") are based on the use of traps and employed in orchards (Sternlicht *et al*. 1990), forests (Weslien & Lindelow 1990; Barclay & Van den Driesche 1984), urban environment (Appel 1998) and food industry (Trematerra & Battani 1987).

A crucial condition of the successful implementation of mass-trapping or unbiased collection of field trapping-data is a detailed knowledge of the critical conditions of the traps efficacy (e.g. Campbell & Hagstrum 2001; Stejskal 1995). Story (1986) stated that "*pest population monitoring is based on carrying out repeated surveys using the same methodology each time so that results can be meaningfully compared*". This means that good monitoring practice requires to use not only the identical trap type but also the identical trap with the identical efficacy, which is not always the same. The capacity of a trap is one of the most important factors influencing the trap-efficacy since it may quickly decline from the increasing occupation of the trap by pests. The opposite extreme is represented by the calendar-based regular replacement and destroying of traps that may be still effective. It is felt that these aspects of trapping are neglected and their omission may

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lead to misinterpretation of the obtained data, a needless increase of the cost of pest monitoring (Stejskal 2002) or ineffectiveness of mass trapping. The reason is probably an operational one. In the past, it has been difficult to measure by traditional methods of area measurement that area of sticky traps occupied by pests or contaminated (Hargrove 1988; Benjamin *et al*. 1968), especially under field conditions. However, the present technique of digital photography (Spring 2000; Weyda 2002) coupled with computer image analysis (e.g. Richardson *et al*. 2001; Daniel *et al*. 1995) provides a new opportunity for an inexpensive and quick method to estimate the instant capacity of traps.

Therefore, the aim of our work was to apply the technique of scientific digital photography and computer-based image analysis to the evaluation of the active and inactive (i.e. occupied/contaminated) area of a trap. In this initial study, we measured the contamination and occupancy of two types of sticky traps by two model pest-species, the German cockroach, *Blattella germanica* Zeller, 1879, and the Mediterranean flour moth, *Ephestia kuehniella* (Linnaeus, 1767). This work is part of a broader research program that intends to develop a general trapping methodology for the agricultural and food industry environment (e.g. Stejskal 2002).

MATERIALS AND METHODS

The pheromone (ZETA) baited sticky traps Ekovet® (sticky board area 7.3 × 19.5 cm) were used to trap moths. The food-lure (GP2) baited sticky traps (LoLine® – sticky board area 6.7 × 18.5 cm) were used to trap cockroaches. Previous work indicated that the GP2 lure (Nalyanya & Schal 2001) and the Lo Line trap (Stejskal 1998) are currently the most efficient tools to trap German cockroaches.

The traps loaded with pests that were included in this study were obtained from previous field research: (i) nine traps with Mediterranean flour moths (*Ephestia kuehniella*) were obtained from the study of Stejskal and Lukáš (2002a); (ii) six traps with German cockroaches (*Blattella germanica*) were obtained from the study of Stejskal and Lukáš (2002b).

Digital images of the traps were obtained by a flatbed scanner (Umax Astra 1200S). The sticky board was fixed on a paper frame to prevent contact of the sticky surface of the trap with the glass surface of the scanner. The acquired digital images were saved in the JPEG (joint photographic experts group) format, with a colour depth of 16.7 million colours, in a resolution of 300 dpi. Subsequently, the individual digital images were analysed by the SigmaScan Pro 5 (Spss Inc. 1999). After processing the image, to correct defects, enhance important aspects of the image, and recognise the objects of interest, the measurement tools in software package were used to count the total number of selected pixels corresponding to moth and moth scales. The number of counted pixels was then divided by the total pixel count of the image to determine the coverage in percentage of the trap by moths and moth scales.

Four parameters of a trap were estimated: "overall active area of trap", "instant active trap area", "instant contamination of trap" and "instant occupancy of trap". **Overall Active Area of Trap** (OAAT) was defined as the total sticky area of a fresh and unused trap. **Instant Active Area of Trap** (IAAT) was defined as the free area of the sticky trap that was not occupied or contaminated at the moment the picture was taken. **Instant Contamination of Trap** (ICT) was defined as the area of sticky trap contaminated by filth produced by pests such as wing-scales and faeces at the moment the picture was taken. **Instant Occupancy of Trap** (IOT) was defined as the area of the sticky trap occupied by insect bodies at the moment the picture was taken. Thus IAAT is simply obtained by:

$$IAAT = OAAT – IOT + ICT \qquad (1)$$

RESULTS

New methods to measure occupancy and contamination of sticky traps

Moths. The image analysis using SigmaScan consisted of enhancing the image quality, separating active image colours, filtering, thresholding and measuring operations. First, the image defects were corrected, balancing contrast, brightness and eliminating uneven lighting (Figure 1a). A Red-Green-Blue (RGB) colour separation function was used to detach the intrusive background grid-like pattern of the moth trap. The dominant colour of the background was found to be a red component ranging from 128 to 225 (Mean = 180.0, SD = 22.8), while the red values of the moth ranged from 1 to 99 (Mean = 65.6, SD = 19.7). Consequently, the red image channel (Figure 1b) was chosen to process

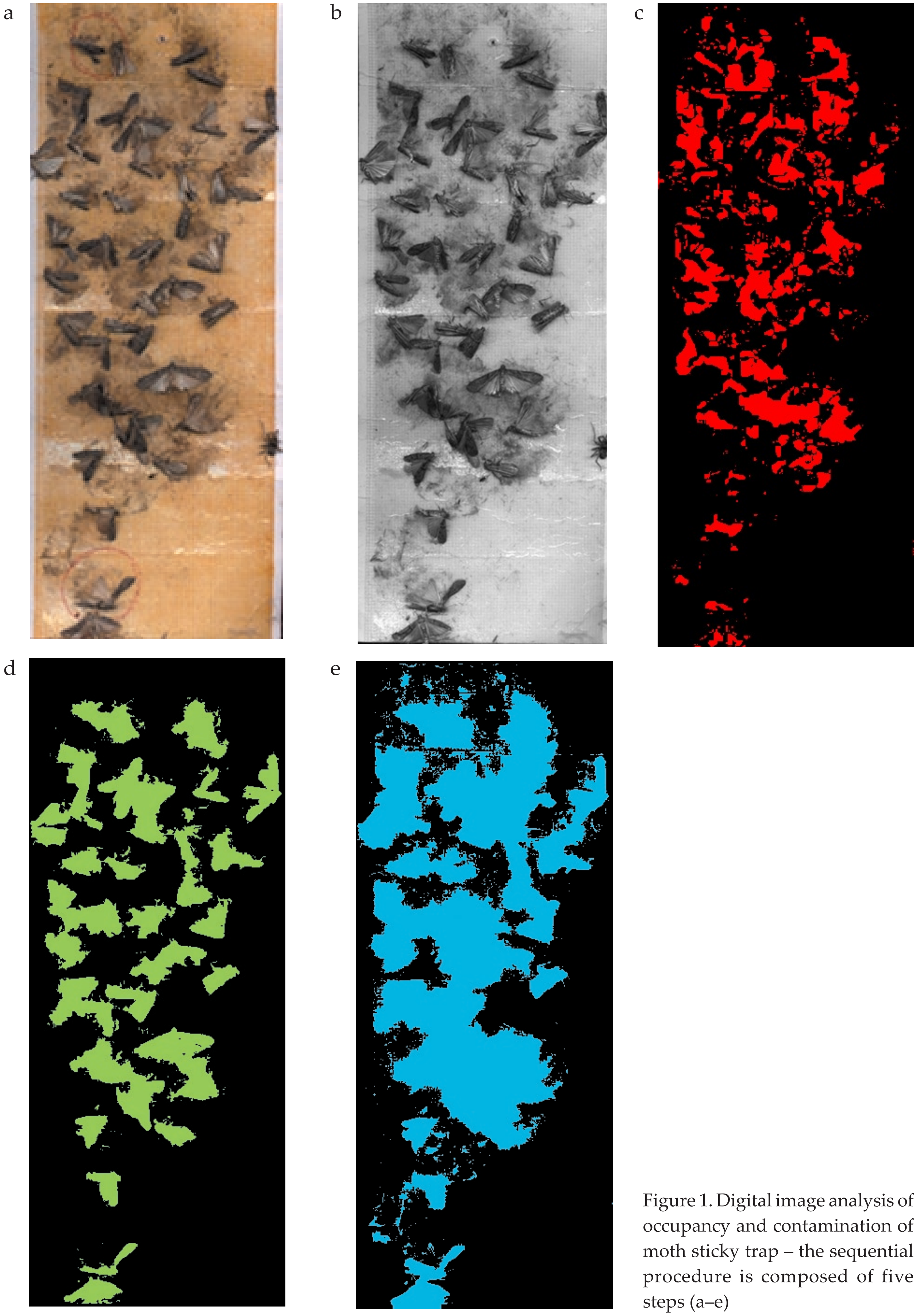

Figure 1. Digital image analysis of occupancy and contamination of moth sticky trap – the sequential procedure is composed of five steps (a–e)

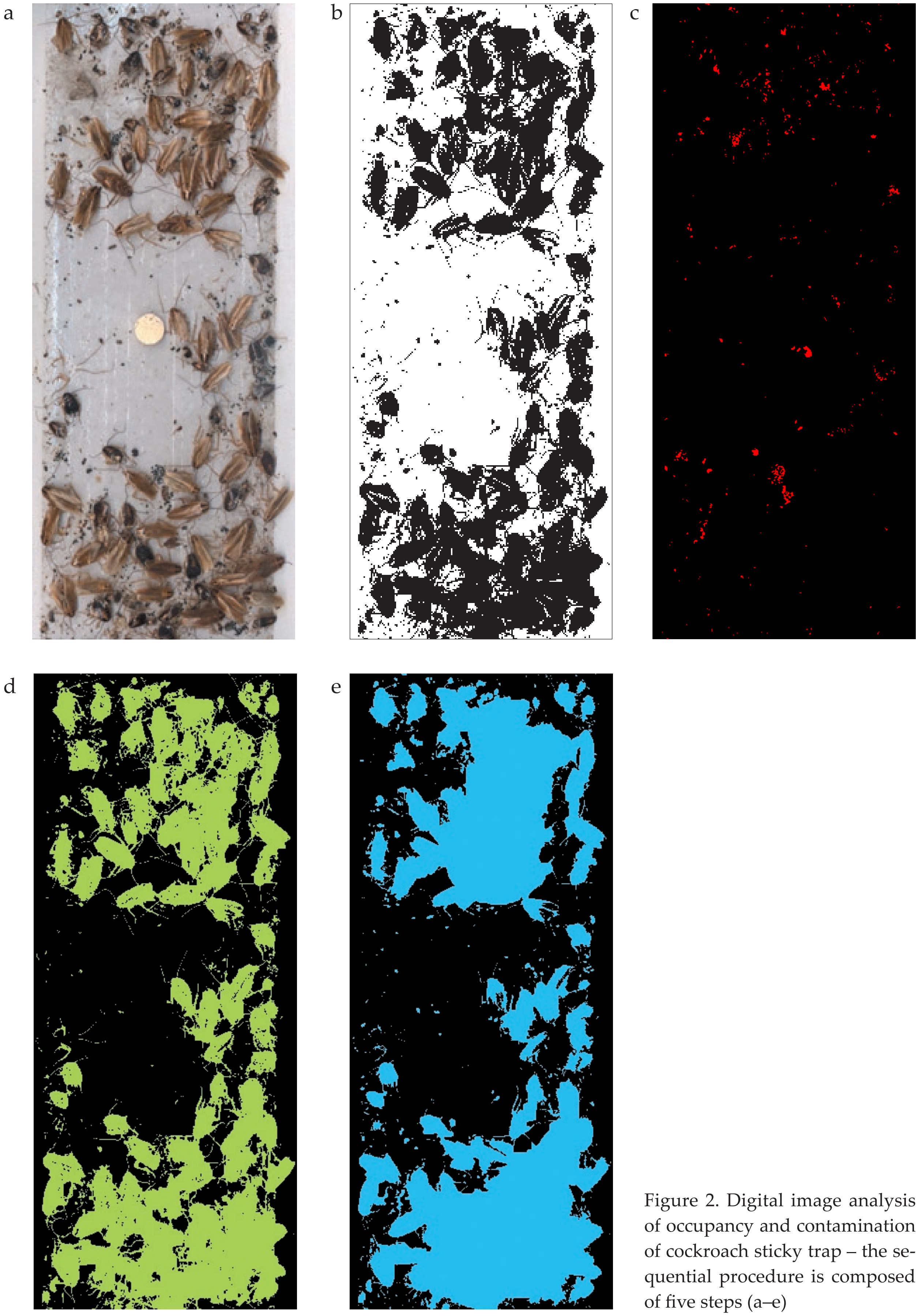

Figure 2. Digital image analysis of occupancy and contamination of cockroach sticky trap – the sequential procedure is composed of five steps (a–e)

by posterise filter (level 2). The number of colour levels was thus reduced to two colours where the black area represented the total space covered by moths and their scales. The moth bodies were identified by the same procedure, but before posterising the contrast level was increased to maximum. The obtained images were then combined by the logical "average" operation into a third image where the moth's scales were separated. The area corresponding to moths, moth scales and uncovered area was identified by thresholding. The red overlay was assigned to moth scales (Figure 1c), the green one to moths (Figure 1d) and the blue one to the sum of both (Figure 1e).

Cockroaches. The procedure of the cockroach-trap analysis preceding the thresholding was different. First, the image defects were corrected balancing contrast, brightness and eliminating uneven lighting (Figure 2a). The colour resolution was changed at the start of the procedure into 1 bit per pixel. The black area represented the total space covered by cockroaches and their faeces (Figure 2b). After thresholding, the blue overlay was assigned (Figure 2e). An edge-tracking algorithm with "fill holes" overlay binary filter was manually applied to separate and threshold (red colour) faeces (Figure 2c). The obtained images were then combined by the logical "average" operation into a third image where the cockroaches' bodies were separated. The green colour represented this area after thresholding (Figure 2d).

Occupancy and contamination of traps by moths and cockroaches

Moths. Digital image analysis revealed that the average ratio of area covered by moth bodies and area covered by moth scales was 1.3 (SD = 0.4) (Table 3). This ratio was fairly stable over all tested traps (Figure 3). Roughly, one trapped moth resulted in a decrease of the available trapping area by 0.8%. The results clearly show that moths are strong trap contaminators, since the sticky trap area contaminated by wing-scales almost equals 100% of the area occupied by moth bodies. Thus, in *Ephestia kuehniella* (EK), $IAAT_{EK}$ can be estimated:

$$IAAT_{EK} \approx OAAT - 1.81 \times IOT_{EK} \qquad (2)$$

or more roughly

$$IAAT_{EK} \approx OAAT - 2 \times IOT_{EK} \qquad (3)$$

Table 1 and Figure 1 are case-examples of the estimation of the occupancy and contamination of a sticky trap, containing 39 individuals of *Ephestia kuehniella*.

Cockroaches. Digital image analysis revealed that the average ratio of area covered by cockroaches and area covered by faeces was 48.7 (SD = 1.9) (Table 4). This ratio was fairly stable over all tested traps (Figure 4). The results show that cockroaches are weak trap contaminators since the sticky trap area that was contaminated by faeces was less

Table 1. Image analysis of occupancy (area of sticky trap covered by moth bodies) and contamination (area of sticky trap covered by wing-scales) of a moth-trap

	Number of pixels	Trap area (%)
Overall active area of trap (sticky trap area)	2 037 075	100
Occupancy (moth bodies)	482 599	24
Contamination (wing-scales)	333 452	16
Instant active trap area	1 384 649	60

Table 2. Image analysis of occupancy (area of sticky trap covered by cockroach bodies) and contamination (area of sticky trap covered by their faeces) of a cockroach-trap

	Number of pixels	Trap area (%)
Overall active area of trap (sticky trap area)	1 797 987	100
Occupancy (cockroach bodies)	865 987	48
Contamination (faeces)	17 113	1
Instant active trap area	914 887	51

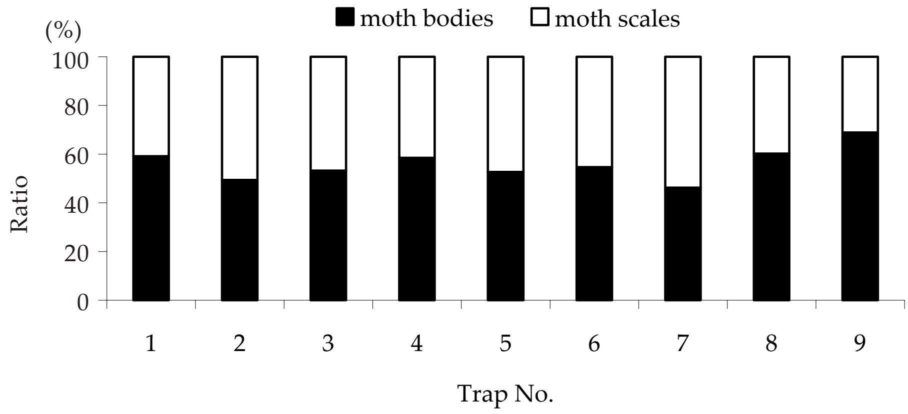

Figure 3. Ratios between the sticky trap (N = 9) areas covered by moth bodies and by their wing-scales

Table 3. Occupancy (area of sticky trap covered by moth bodies) and contamination (area of sticky trap covered by wing-scales) of moth-traps expressed in pixels (px)

Trap	Moth bodies area (px)	Wing-scales area (px)	Ratio
1	482 599	333 452	1.45
2	217 981	223 361	0.98
3	556 867	489 630	1.14
4	431 791	306 190	1.41
5	266 424	239 422	1.11
6	335 796	278 603	1.21
7	205 373	238 851	0.86
8	123 524	81 623	1.51
9	201 588	91 087	2.21

Table 4. Occupancy (area of sticky trap covered by cockroach bodies) and contamination (area of sticky trap covered by faeces of cockroaches) of cockroach-traps expressed in pixels (px)

Trap	Cockroach bodies area (px)	Faeces area (px)	Ratio
1	865 987	17 113	50.60
2	1 529 227	32 079	47.67
3	1 044 078	21 564	48.42
4	967 854	18 634	51.94
5	345 786	7 425	46.57
6	463 277	9 835	47.10

than 2% of the area occupied by cockroach bodies. Thus in *Blattella germanica* (BG), $IAAT_{BG}$ can be estimated:

$$IAAT_{BG} \approx OAAT - 1.021\ IOT_{BG} \quad (4)$$

or more roughly

$$IAAT_{BG} \approx OAAT - IOT_{BG} \quad (5)$$

A detailed result of occupancy/contamination analysis of a medium covered trap is shown as an example in Table 2 and Figure 2. The trapped individuals of *Blattella germanica* covered 48% of the active trap area while their faeces covered only 1%.

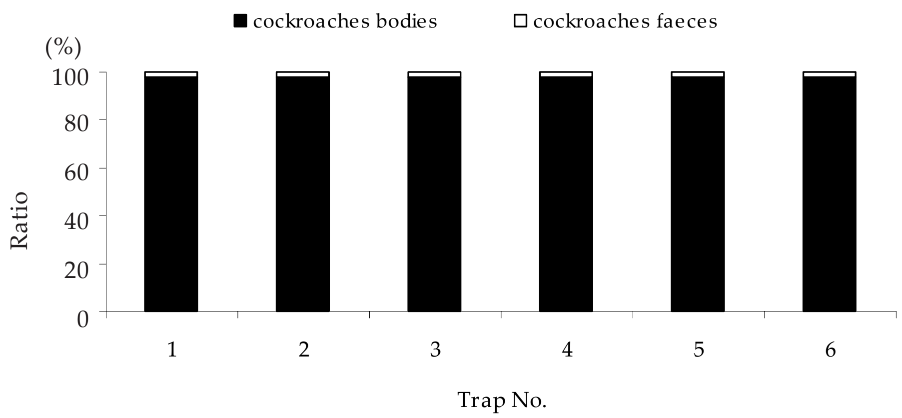

Figure 4. Ratios between the sticky trap (N = 6) areas covered by cockroach bodies and by their faeces

The results indicate that moths are heavy contaminators while cockroaches are weak contaminators of sticky traps.

DISCUSSION

Computer-based image analysis (CBIA). CBIA is used effectively in a broad range of applications, from satellite images to industrial quality control of macroscopic manufactured items, to light and electron microscopy of material structures, biological, geological or archaeological specimens, integrated circuits and so forth (Brosnan & Sun 2002). The processing of the raw image to enhance interesting details or to extract quantitative information is a vital step in the use of images as scientific data. Generally, these methods are concerned with extracting a few numerical values from the image, such as the number, size, shape or location of objects. In other cases, global structural parameters such as measures of the volume and surface of structures present are of interest.

CBIA-based evaluation of moth and cockroach traps. In this study CBIA was used, for the first time, to measure the instant active area of insect traps. We showed how to measure the occupancy and contamination of sticky traps by the two model pest-species the Mediterranean flour moth, *Ephestia kuehniella* (Figure 1) and German cockroach, *Blattella germanica* (Figure 2). We found that the per-individual decrease of the instant active area of the sticky surface was much higher in the moths than in cockroaches because of the extensive contamination of the trap surface by wing-scales of the moths. The sticky trap area contaminated by scales is almost equal to the area occupied by moth bodies (Table 1). The contamination of a trap by wing-scales, that are hard to see with the naked eye, decreases the instant active area of a trap to a large extent. Clearly, to evaluate the instant active area of a trap solely by the area covered with moth-bodies may give an erroneous impression of the real instant active area of a trap. The contamination of the sticky traps by cockroach faeces amounts to only $1/50^{th}$ of the area occupied by cockroach bodies (Table 2). With such an extremely low level of contamination it appears that the occupancy of the sticky surface by cockroach bodies gives a good estimate of the active area of a trap. Field observations confirmed the good efficacy of traps occupied by cockroaches. For example, Appel (1998) reported that in his study the number of daily captures of cockroaches did not change over time in most trap locations, indicating that previously captured cockroaches did not significantly affect the efficacy of traps. Nevertheless, the overall number of captured cockroaches was rather low in his study, i.e. total cumulative captures per 7 d ranged from 21 to 84 cockroaches per trapping site. It is a question whether trap efficacy remains unaffected at higher population densities, e.g. if pest shelters contain thousands of cockroach individuals, as reported by Reierson (1995).

Conclusions

The new method of measuring the capacity of sticky traps by CBIA appears promising from a practical point of view since it is easy and quick. The results with two types of sticky traps used to monitor the Mediterranean flour moth or the German cockroach indicated that moths were heavy contaminators while cockroaches were weak contaminators of sticky traps. Once data on the instant occupancy, contamination and active area of a trap have been obtained, it must be decided whether the trap is either efficient enough for a given trapping purpose or not and must be replaced. The evaluation of the instant trap efficacy should be based on the pre-estimated relationship between the efficacy of traps and the % of active area of a trap. We think, however, that data to make these calculations are currently not available for most of the traps and pests, constituting an area for additional work in laboratory and field.

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Souhrn

Lukáš J., Stejskal V. (2003): **Využití obrazové analýzy pro stanovení obsazenosti a kontaminace lepových lapačů škůdců.** Plant Protect. Sci., **39**: 52–60.

Lapače jsou hojně používaným prostředkem pro monitorování výskytu škůdců. Znalost jejich účinnosti je nezbytná pro jejich efektivní používání a interpretaci výsledků. Okamžitá aktivní plocha lapače (tj. momentálně dostupná plocha schopná zachycovat monitorovaného škůdce) je určující pro účinnost lapačů. Zjišťování velikosti této plochy je však obtížné. Pro hodnocení okamžité aktivní plochy lapače, obsazenosti (tj. plocha obsazená těly škůdců) a kontaminace (tj. plocha kontaminovaná nečistotami, např. výkaly, šupinkami křídel motýlů) navrhujeme využití metody obrazové analýzy. Vyvinutou metodiku demonstrujeme na dvou různých typech lapačů určených pro monitorování zavíječe moučného (*Ephestia kuehniella*) a rusa domácího (*Blattella germanica*). Zjistili jsme, že skladištní zavíječi snižují okamžitou aktivní plochu lapačů rychleji než rusové. Důvodem je výrazná kontaminace lepového lapače šupinkami z křídel zavíječů. Plocha kontaminovaná šupinkami je téměř shodná s plochou, kterou zaujímají samotní zachycení motýli. Oproti tomu rusové kontaminovali lapače svými výkaly výrazně méně. Plocha kontaminovaná výkaly byla menší než 2 % plochy, kterou zabírali samotní rusové. Výsledky naznačují, že zavíječi jsou silnější kontaminátoři lepových lapačů než rusové.

Klíčová slova: monitorování; lapače; obrazová analýza; *Ephestia kuehniella*; *Blattella germanica*

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