



Evaluation of conventional odour attractants for *Glossina brevipalpis* and *Glossina austeni* (Diptera: Glossinidae) in South Africa

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ABSTRACT

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The components of the synthetic ox-odour used in Zimbabwe against *Glossina pallidipes* and *G. m. morsitans* were evaluated for the attraction of *G. brevipalpis* and *G. austeni* in South Africa. The Zimbabwe mixture (Zim-mix), which consisted of acetone and a 1:4:8 mixture of 3-*n*-propyl phenol, 4-methyl phenol and 1-octen-3-ol, increased the catches of *G. brevipalpis* by c. 2, 1–4, 4 times compared to when no odours were used. One of the odour components, namely 3-*n*-propyl phenol, did not significantly increase the size of the catches. Acetone was an essential component for *G. brevipalpis*, especially during the warm and wet season when it acted synergistically with high doses of 1-octen-3-ol and 4-methyl phenol. The most attractive odour combination for *G. brevipalpis* was 1-octen-3-ol released at 2, 3–9, 1 mg/h with 4-methyl phenol at c. 15, 5 mg/h and acetone at c. 350 mg/h. This combination increased the catches by another 2, 3–2, 8 times when compared to the Zim-mix and 10, 1–12, 3 times compared to 'no odour'. None of the odour components was attractive for *G. austeni*. None of the components was repellent for either species.

Keywords: Diptera: Glossinidae, *Glossina austeni*, *Glossina brevipalpis*, odour attractants, South Africa, tsetse flies

INTRODUCTION

Tsetse flies recognize potential hosts by olfactory and visual cues. They approach a stationary host or target baited with odour by upwind flights (Torr 1989; Gibson, Packer, Steullet & Brady 1991; Brady & Griffiths 1993; Willemsse & Takken 1994; Groenendijk 1996) modulated by olfactory stimuli, with visual responses operating only at short range. Odours have, therefore, been used to enhance the effects of shape and colour in the attraction of tsetse flies to traps and targets (Snow 1980).

Studies in Zimbabwe (Vale 1974a, 1977) demonstrated that ox-breath is an important odour bait for *Glossina morsitans morsitans* and *G. pallidipes*. One

of the effective components of ox-breath is carbon dioxide (Vale 1980; Owaga 1984), but it is too expensive and inconvenient to use. Acetone and a number of aldehydes and other ketones are attractive to tsetse (Vale 1980) and are cheaper and more convenient to use. The most attractive element in ox-breath was identified as 1-octen-3-ol (henceforth referred to as octenol) (Hall, Beever, Cork, Nesbitt & Vale 1984). This attractant enhances the effects of ketones and CO₂ (Vale & Hall 1985a). Butanone was identified as a substitute for acetone and can be used at a lower dosage rate (Vale & Hall 1985b). A further breakthrough occurred when Owaga (1985) demonstrated in Kenya that the urine of the African buffalo (*Syncerus caffer*) could be used for the attraction of *G. pallidipes*. Much of the efficacy of the urine is due to phenols (Hassanali, McDowell, Owaga & Saini 1986; Bursell, Gough, Beever, Cork, Hall & Vale 1988;

Owaga, Hassanali & McDowell 1988; Vale, Hall & Gough 1988a). Of these 4-methyl phenol and 3-*n*-propyl phenol have been found to be the most compelling for tsetse flies (Saini 1990; Saini & Hassanali 1992) and act synergistically as the crucial components of the phenolic mix (Owaga *et al.* 1988; Vale *et al.* 1988a). The responses to the above substances were studied with *G. pallidipes* in Somalia (Torr, Parker & Leigh-Browne 1989) and with *G. longipalpis*, *G. palpalis* and *G. tachinoides* in West Africa (Cheke & Garms 1988; Jaenson, Barreto dos Santos & Hall 1991; Küpper, Späth & Kröber 1991). It was concluded that some of the chemicals are promising attractants that can be used when capturing tsetse flies for sampling or control purposes.

While workers in Kenya used acetone and cow urine (Okech & Hassanali 1990), the Zimbabwean workers used blends of synthetic octenol, 4-methyl phenol and 3-*n*-propyl phenol. Owaga (1992) tested odours which might attract *G. austeni*. These included African buffalo and cow urine, acetone, 3-*n*-propyl phenol, 4-methyl phenol, and carbon dioxide in the form of dry-ice. In Kenya, Kyorku (personal communication 1994) also conducted studies on attractive odours (octenol and acetone) for *G. pallidipes* and *G. brevipalpis*. In 1992 in South Africa, when a target trial to control *G. brevipalpis* commenced in the Hluhluwe-Umfolozi Game Reserve (Kappmeier, Nevill & Bagnall 1998), no work had previously been conducted on odour attraction for *G. brevipalpis*. For this reason the Zimbabwe approach was chosen in the trial and its value appraised.

The present work investigated the effectiveness of the Zimbabwe odour mixture (Zim-mix) and its components as attractants for *G. brevipalpis* and *G. austeni*. In addition, the optimal dosage rates of the components, which were found to be most effective in attracting the flies, were determined.

METHODS

The research was conducted at the Hellsgate Military Base (28°02'40"S, 32°25'50"E) on Lake St Lucia in north-eastern Kwazulu-Natal Province where the Hellsgate Tsetse Research Station was established (Kappmeier *et al.* 1998). The area has been described in detail by Kappmeier (1997).

In a number of separate experiments the components of the synthetic ox-odour used in Zimbabwe (Vale *et al.* 1988a) were tested at the standard doses of the Zim-mix. The most promising odours were then tested at various doses and in various combinations. All experiments used the Zim-mix as the control. A treatment in which no odours were used was added as the 'no odour' treatment.

The Zim-mix consisted of a 1:4:8 mixture of 3-*n*-propyl phenol, octenol and 4-methyl phenol placed in a

polythene sachet plus acetone released from a separate container. An attempt was made to ensure that the components evaporated at approximately the same rate as they did in Zimbabwe (Vale, Lovemore, Flint & Cockbill 1988b) i.e. acetone at 500 mg/h, 3-*n*-propyl phenol (3npp) at 0,1 mg/h, octenol (oct) at 0,4 mg/h and 4-methyl phenol (4mp) at 0,8 mg/h. Octenol and the phenols were dispensed from heat-sealed sachets made from low density polyethylene tube (wall thickness 150 microns). The surface area was varied (1–75 cm²) in order to produce different release rates. Acetone was dispensed from a glass bottle with a hole in the lid from which the release rates were controlled by varying the diameter of the hole. The average daily release rates (mg/h) of the various chemicals used in the experiments were measured by weighing the dispensers 24-hourly. Sachets were also weighed separately during the day (10–12 hourly) during the period of tsetse activity since this period is more significant for sampling purposes and would differ from the 24-hourly release rates due to ambient atmospheric temperature effects. Table 1 shows the sachet sizes as used in this study, the ratios of the components used to produce various odour combinations with their recommended release rates, and the average release rates as obtained by Kappmeier (1997).

The odour baits were placed ± 40 cm downwind of an electric grid system, consisting of a framework of wires at both sides of a visual or non-visual cloth target or netting "insert" (Vale 1974b). The electric target used in this study consisted of a 1 m wide x 1 m high pthalogen blue (p.blue) cloth which was flanked by a 0,5 m wide x 1,0 m high non-visual terylene net. This target/net combination was chosen because it was found effective for both *G. brevipalpis* and *G. austeni* during the initial studies on colour targets (Kappmeier 1999) and was therefore used as standard throughout all odour experiments. The grid was placed in a perpendicular position at ground level in situations frequented by the flies. The grids were electrified by means of a 12 V battery and electrical units which increased the voltage to 20 000 V. Flies that collided with the electric grid were stunned and retained on a tray painted with a sticky layer of polybutene, which was placed beneath the grids. All sites of target positioning were a minimum of 200 m apart so that the different odour-baits would not interfere with each other. The electric grids were operated from noon until dark, during which period both *G. brevipalpis* and *G. austeni* were active.

All treatments under comparison were incorporated into a series of one to three Latin squares of treatments x days x sites. The treatments had a total of 5–24 replicates (one replicate being one treatment operating at one site for one day). Treatments were replicated until a statistically sound result was obtained.

TABLE 1 Odour components and combinations of the Zimbabwe odour mixture, with the various component ratios, dispenser dimensions and release rates

Odour ^a	Ratios	Dispenser dimensions	Recommended Zimbabwe release rate (mg/h)	Average daytime release rate obtained in RSA (mg/h)
Odours released from sachets		Sachet area cm ²		
3npp:oct:4mp	1:4:8	75,0	1,3	1,22
3npp		5,8	0,1	0,11
oct		23,1	0,4	0,57
4mp		46,2	0,8	0,97
3npp:oct	1:4	28,9	—	0,60
3npp:4mp	1:8	52,0	—	0,69
oct:4mp	4:8	69,2	—	1,03
¼ (oct:4mp)	4:8	17,3	—	0,28
1/16 (oct:4mp)	4:8	4,3	—	0,10
Odours released from bottle		Diameter of aperture (mm):		
Acetone	—	1,5	—	100,0
		4,0	—	225,0
		6,0	500,0	350,0
		20,0	—	1 100,0

^a 3npp = 3-*n*-propyl phenol
 oct = 1-octen-3-ol
 4mp = 4-methyl phenol

The daily catches (*n*) were subjected to an analysis of variance (ANOVA), following an estimated skewness for normal distribution and a $\log_{10}(n)$ or, where zero catches were obtained, a $\log_{10}(n + 1)$ transformation. The ANOVA was followed by Bonferroni's multiple range test to compare treatment means (Van Ark 1981). The critical level of *P* was taken as 0,05.

When sufficient tsetse numbers were present, male and female catches were analyzed separately or otherwise the data was pooled for analysis of the total catch. The catch index was estimated by expressing the detransformed mean catch of the test treatment as a proportion of the detransformed mean control (standard) catch (Zim-mix). Thus catch indices > 1 indicate that the odour is more attractive and < 1 indicate the odour is less attractive than the Zim-mix.

EXPERIMENTS AND RESULTS

A series of experiments was conducted between 1992–1996. The results of preceding experiments dictated the design of subsequent experiments. The experiments are therefore explained and discussed in sequence. The results of the various odour treatments are summarized in Fig. 1–5. These are given as indices of increase of the detransformed mean catches of the various treatments relative to the control treatment. Unless stated otherwise, the Zim-mix acted as the control treatment and 'no odour' was tested in all experiments as a second standard. When possible, female and male catches are indica-

ted separately also relative to the total catch. Treatments that are significantly different from the control in the same experiment are indicated with an asterisk.

Single and combinations of the odour components of the Zim-mix

Four experiments were conducted between 1992–1995 with the Zim-mix components to determine not only if they were attractive for *G. brevipalpis* and *G. austeni* but also whether all the components were equally important. The four components of the Zim-mix were tested singly and in all possible combinations against 'no odour' and the standard Zim-mix as set out in Fig. 1. In order to make a more confident selection of an odour, each treatment had 18 replicates. The results for the various odour combinations are summarized for the total catches (pooled sexes since no difference was obtained between sexes) of *G. brevipalpis* and *G. austeni* in Fig. 1A and B respectively.

For *G. brevipalpis* the Zim-mix was significantly better than 'no odour' (index = 2,1–4,4). Against single components the Zim-mix was also significantly better than 3npp (index = 2,6), acetone (index = 2,3) and 4mp (index = 2,2) but not significantly better than octenol. None of the single components increased the total catches significantly when compared to 'no odour'. Against combinations of components the Zim-mix was also significantly better than 3npp:oct, 3npp:4mp and oct+acetone (index = *c.* 2,3–3,3) and

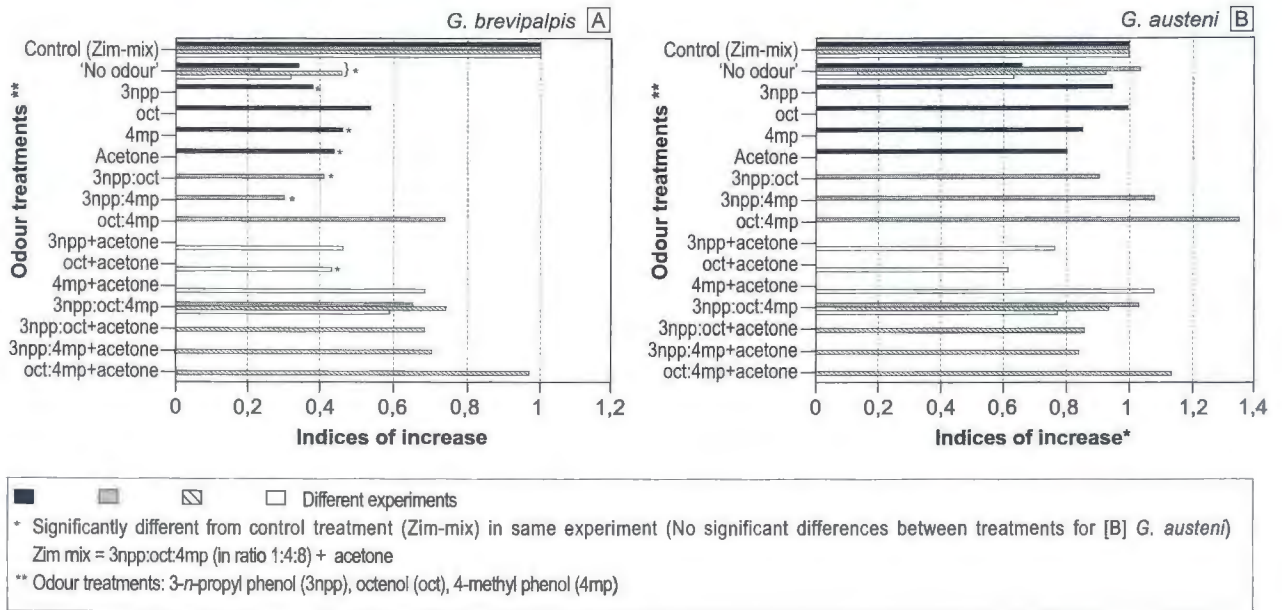


FIG. 1 Attractiveness of various combinations of some components of synthetic ox-odour to combined male and female catches of (A) *G. brevipalpis* and (B) *G. austeni*

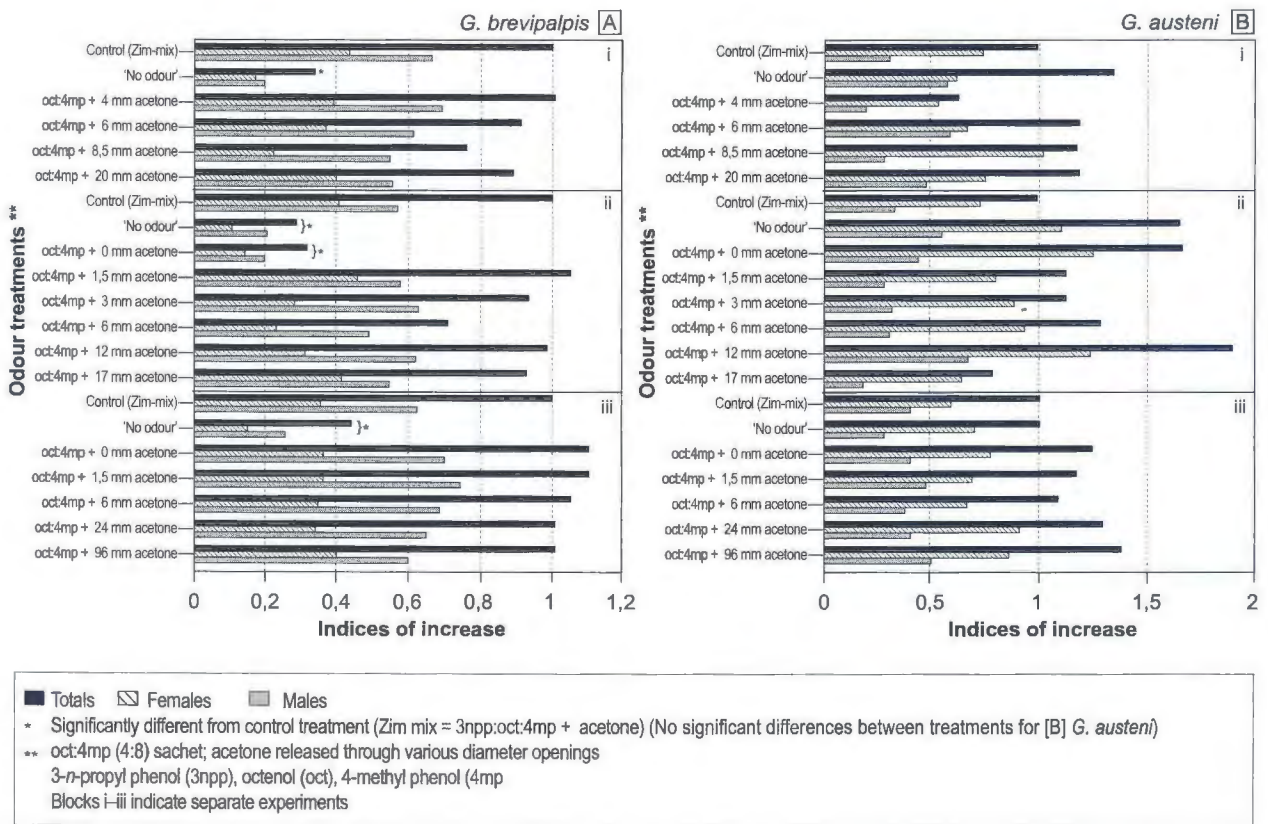


FIG. 2 Summary of the results of three experiments (i-iii) to determine the effect of acetone release rates on the attraction of (A) *G. brevipalpis* and (B) *G. austeni*

noticeably better than the remaining combinations except for oct:4 mp + acetone. This combination, except for the Zim-mix, is the only one that actually increased the catches significantly compared to 'no odour' (index = 2, 1). The results, therefore, indicated that, for *G. brevipalpis*, 3npp was not essential in the attractant mixture and could perhaps be excluded in future.

For *G. austeni* there was no significant difference in attraction between the Zim-mix and 'no odour'. The same applied to single components and combinations, although a mixture of oct:4mp seemed promising (Fig. 1B).

Optimal doses of the most important components of the Zim-mix

Experiments were conducted to see whether any change in the release rates of these components would alter catches. The release rates of the components were effected by either varying the size of the acetone release openings, or the size or number of sachets in the case of oct and 4mp. The experiments were also designed so that the future exclusion of 3npp from the odour mixture could be fully justified.

Acetone dose rates

In three experiments the aperture of the release opening for acetone was varied while the mixture comprising oct and 4mp in the sachets at a ratio of 4:8 (i.e. as for the Zim-mix but excluding 3npp) was kept constant. At first several preliminary release rates were tested in two experiments to obtain an indication of the range to be more comprehensively investigated in the final experiment. In the first experiment the acetone release apertures were 4 mm, 6 mm, 8.5 mm and 20 mm in diameter respectively, and in the second they were 0 mm, 1.5 mm, 3 mm, 6 mm, 12 mm and 17 mm in diameter respectively. Six and eight replicates were carried out in the two experiments respectively. In the final experiment, 21 replicates were performed with the apertures for the acetone release openings being 0 mm, 1.5 mm, 6 mm, 24 mm and 96 mm respectively.

The results of these trials are summarized in Fig. 2A and B for *G. brevipalpis* and for *G. austeni* respectively. For *G. brevipalpis* (Fig. 2A) there were no significant differences in catches between the various dose rates of acetone used in the three experiments, i.e. a low rate (c. 100 mg/h) of acetone was as attractive as that of a high rate (c. 14 500 mg/h). In the second experiment (eight replicates, conducted in May 1995) all treatments with acetone (c. 100–960 mg/h), including the control treatment, increased catches significantly when compared to the treatment without acetone (0 mm aperture) and also to 'no odour'

[Fig. 2A (ii)]. This suggests that acetone has a strong synergistic effect for the attraction of *G. brevipalpis* even when it is released at very low rates. This finding was, however, contradicted in the final experiment (21 replicates, conducted in June, August and December 1995) in which no significant difference was found between the treatments with varying release rates of acetone (1.5–96.0 mm apertures, i.e. c. 100–14 500 mg/h) and with no acetone suggesting this component was unimportant [Fig. 2A (iii)]. However, when the three individual Latin squares, conducted for the last experiment, were examined separately it became apparent that while the absence of acetone did not decrease catches during the cooler and drier months (i.e. June to August) its presence did seem to play a slight synergistic role in the warm and wet season (December). The results, therefore, suggest that the efficiency of acetone for the attraction of *G. brevipalpis* may vary with the meteorological differences of the seasons.

Furthermore, no significant difference was found between the results when the treatment consisted of oct:4mp sachets plus acetone released through a 6 mm opening and those of the standard control (Zim-mix). This proved once again that 3npp is not an essential component of the *G. brevipalpis* odour mix.

For *G. austeni* no significant differences were found between any of the odour treatments (Fig. 2B).

Octenol/4-methyl phenol dose rates

ACETONE INCLUDED

In the first experiment (as set out in Fig. 3) acetone was included with all treatments as a constant, released through a 6 mm diameter opening (as when Zim-mix is used), while the release rate of oct:4mp was varied either by using the original sachet size, or by reducing it to a $\frac{1}{4}$ or $\frac{1}{16}$ of the original size, or by increasing the numbers of the original sachet (i.e. 4 and 16 times), or by using acetone only (i.e. 0 = no sachet). Twenty-four replicates were carried out during May, July and November 1995.

The results of this experiment are given in Fig. 3A and B for *G. brevipalpis* and *G. austeni* respectively. The results show a significant increase (index = 2, 6) in the catches of *G. brevipalpis* (Fig. 3A) with 16 sachets of oct:4mp [i.e. 16(oct:4mp)] when compared to the Zim-mix. Both four and 16 sachets increased the catches significantly (2.2 and 3.6 x respectively) when compared to a single sachet. No significant difference was found between the catches of one oct:4mp sachet and the Zim-mix control. This again proved the insignificance of 3npp.

For *G. austeni* there were no significant differences between the catches obtained with any of the treatments (Fig. 3B).

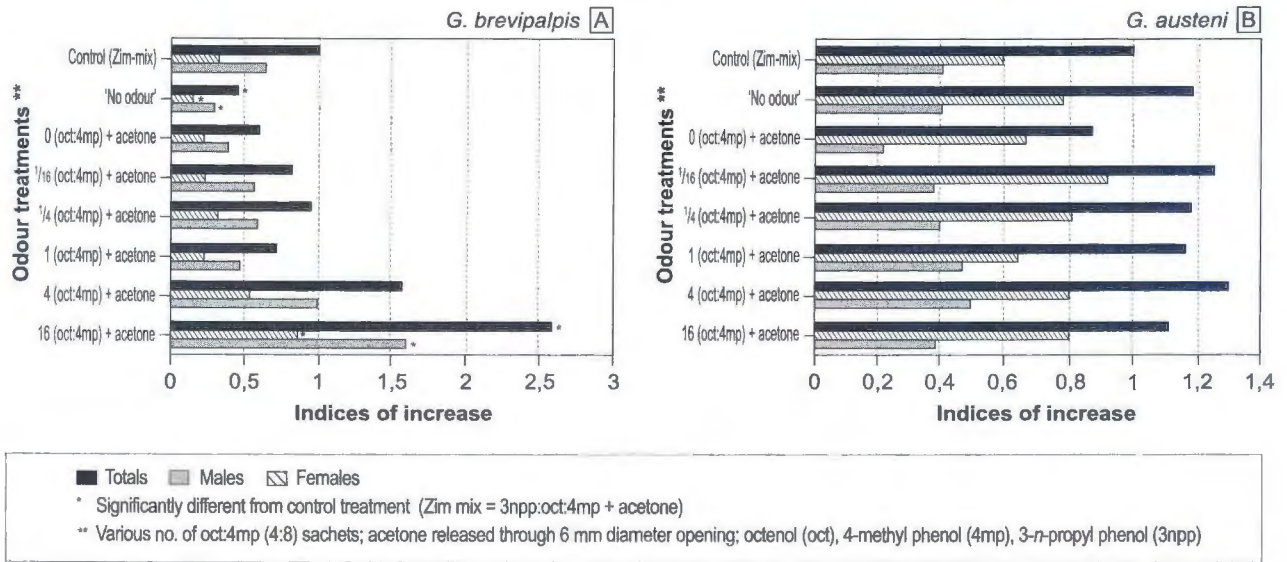


FIG. 3 Effect of various octenol:4-methyl phenol doses on the attraction of (A) *G. brevipalpis* and (B) *G. austeni* in the presence of acetone

ACETONE ABSENT

In the next three experiments (indicated blocks i–iii in Fig. 4) different combinations of release rates of octenol and 4-methyl phenol (one, four and 16 sachets of each separate component) were tested to determine the optimal release rates for each of the two individual components. Since it had been demonstrated for *G. brevipalpis* (Fig. 2A) that acetone might be excluded (at least in the dry season) and that an oct:4mp sachet on its own was as effective as the Zim-mix for the attraction of this species, acetone was excluded from the various baits in these experiments and an oct:4mp sachet [i.e. 1(oct:4mp)] was included in all three experiments in order to compare the results obtained with it against the others. The oct:4mp combinations were distributed in the three experiments as set out in Fig. 4A and B. Five replicates were carried out for the first experiment [Fig 4 (i)] and six replicates for the other two [Fig. 4 (ii and iii)] during March to April 1996.

The results are given in Fig. 4A and B for *G. brevipalpis* and *G. austeni* respectively. Owing to low catches only total catches were included in Fig. 4B for *G. austeni*. For *G. brevipalpis* no significant differences were found between any of the oct:4mp doses and 'no odour' treatments in all three experiments [Fig. 4A (i–iii)]. The Zim-mix increased the catches of this species significantly (index = 4,3) when compared to those of the 'no odour' treatment [Fig. 4A (ii)] and also when compared to those of the 1(oct:4mp) treatment (index = 6,8) [Fig. 4A (iii)]. The results of previous experiments had indicated that acetone did not increase the *G. brevipalpis* numbers during the cool and dry season, but the poor catches

obtained without acetone in these three experiments conducted in late summer show that it might perhaps play a synergistic role in the warm and wet season.

The Zim-mix increased catches of *G. brevipalpis* by c. 1,9 fold when compared to those when four oct:4mp sachets [i.e. 4(oct) + 4(4mp)] were used [Fig. 4A(ii)] and was as effective as 16 oct:4mp sachets [i.e. 16(oct) + 16(4mp)] [Fig. 4A(iii)], all without acetone. In the previous experiments, however, when acetone was present, it was found that the four and 16 sachets of oct:4mp increased the catches (by 1,6 and 2,6 fold respectively) (Fig. 3A) when compared to the catches obtained when Zim-mix was used. This reinforced the observation that acetone might have a synergistic effect on the catches and that this effect may vary according to the season.

For *G. austeni* (Fig. 4B) no significant differences were found between any of the treatments.

Synergistic effect of acetone

The above experiments suggested that the synergism of acetone for *G. brevipalpis* might be seasonal. To elucidate this, the next experiment was designed to determine whether acetone did indeed act synergistically during the warm and wet season. The experiment included various combinations (four and 16 times) oct and 4mp sachets, each treatment being either with acetone released at c. 350 mg/h through a 6 mm diameter aperture or without it and are set out in Fig. 5. The same controls were used as in the experiments described above. Ten replicates were carried out during April 1996 towards the end of the warm and wet season and another 10 replicates

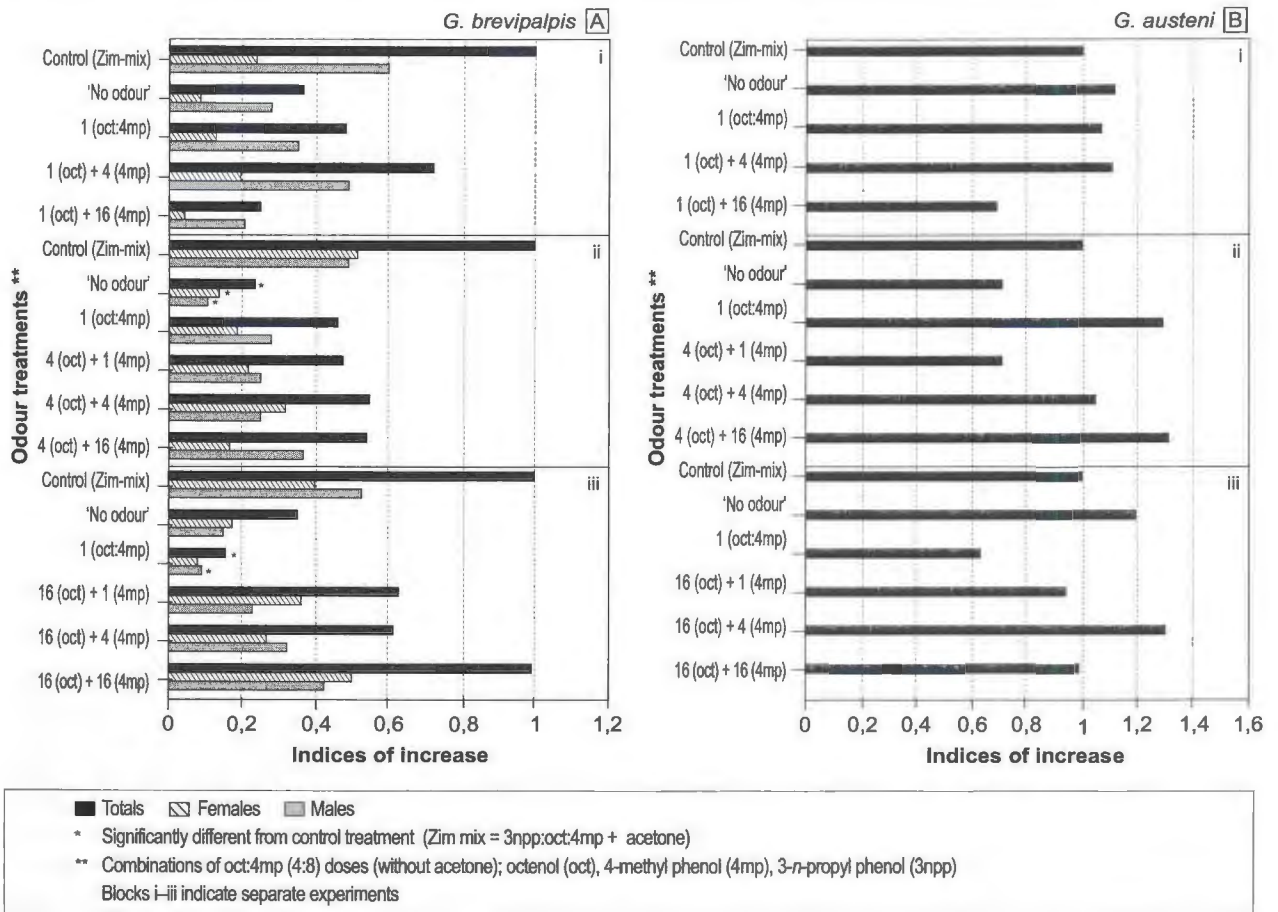


FIG. 4 Summary of results of three experiments to determine the effect of various doses of octenol:4-methyl phenol on the attraction of (A) *brevipalpis* and (B) *G. austeni* in the absence of acetone

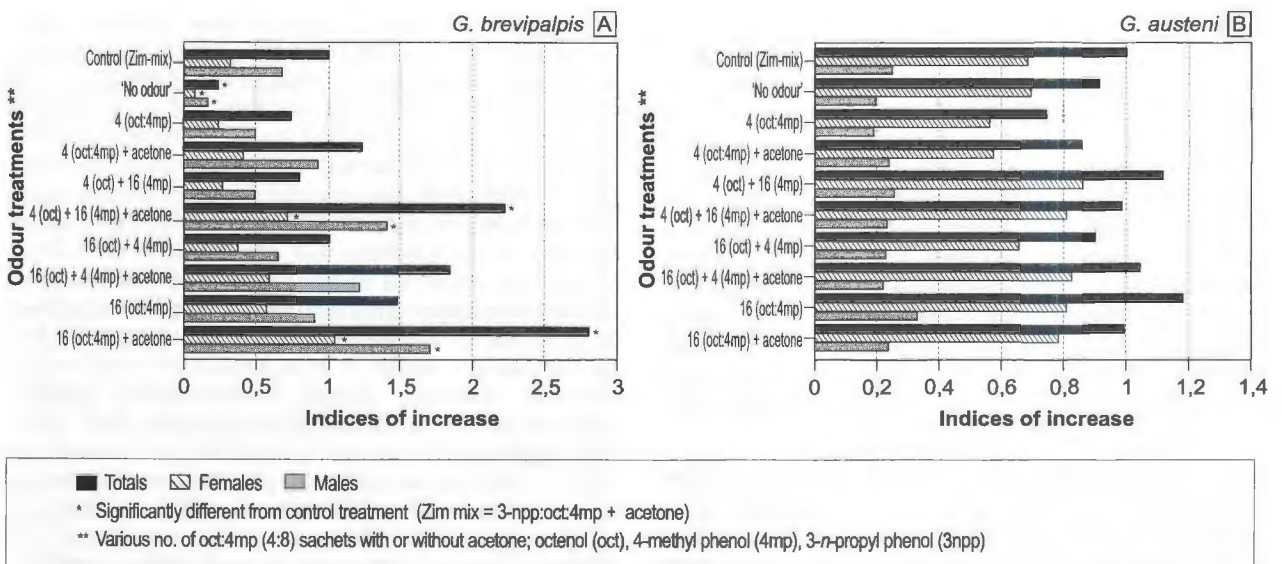


FIG. 5 Effect of acetone, when added to various doses of octenol:4-methyl phenol, on the catches of (A) *G. brevipalpis* and (B) *G. austeni*

during December 1996 and January 1997 which is during the warm and wet season.

The results are given in Fig. 5A and B for *G. brevipalpis* and *G. austeni* respectively. For *G. brevipalpis* (Fig. 5A) it is clear that the addition of acetone increased the catches (1,7–2,8 fold) when compared to the corresponding treatments without acetone, although this was only significant when it was added to the combination of 4(oct)+16(4mp) and to 16(oct:4mp) which produced increases in catches of 2,8 and 1,9 fold respectively. These two treatments with acetone also increased the catches of this species significantly (index = 2,3 and 2,8 respectively) compared to those of the standard control treatment (Zim-mix) and *c.* 10,1 and 12,3 times compared to 'no odour' targets. The Zim-mix was significantly better (index = 4,4) than 'no odour'.

For *G. austeni* (Fig. 5B) no significant differences were found between any of the treatments and no synergistic effect of acetone was observed.

DISCUSSION

The current research confirmed that the Zim-mix is effective in attracting *G. brevipalpis* to targets as it increased the catches by *c.* 2,1–4,4 fold when compared to those of targets which were not baited. It was more attractive for *G. brevipalpis* than were its individual components and other combinations of these components. It did, however, become evident that the four components were not equally effective and that not all were necessary or suitably cost-effective.

It was proven in several experiments that the presence of 3-*n*-propyl phenol in the Zim-mix did not make a significant difference to the catch size of *G. brevipalpis* and that this component could, with confidence, be excluded from the Zim-mix. This result was contrary to the findings for *G. pallidipes* in Zimbabwe where it was found that 3-*n*-propyl phenol increased the catches of this species by 50% and is a powerful synergist for 4-methyl phenol (Vale *et al.* 1988a). Owaga *et al.* (1988) also indicated that 3-*n*-propyl phenol was, together with 4-methyl phenol, important for *G. pallidipes* in Kenya. The omission of 3-*n*-propyl phenol in the *G. brevipalpis* odour bait at Hellsgate could, however, reduce the cost of the synthetic ox-odour due to the high costs involved in its synthetic manufacturing and as a foreign merchandise (US\$ 1 600/kg).

In this study octenol and 4-methyl phenol were the main components involved in the attraction of *G. brevipalpis*. When released at high doses, octenol and 4-methyl phenol (i.e. *c.* 2,3–9,1 mg/h and *c.* 15,5 mg/h respectively), in the presence of acetone released at *c.* 350 mg/h, gave a significant *c.* 2,3–2,8

times increase in the catches of *G. brevipalpis* when compared to Zim-mix. In the first experiments with octenol in Kenya, at 0,5 mg/h, it did not increase catches of this species significantly (Kyorku, Brightwell & Dransfield 1990), although at a later stage Brightwell & Dransfield (1997) found the addition of octenol produced a significant increase in catches of females. Octenol was attractive for *G. longipalpis* in West Africa (Jaenson *et al.* 1991) and *G. p. palpalis* in Liberia (Cheke & Garms 1988). Küpper *et al.* (1991) found phenols to have greater attractiveness at higher rates of release for *G. tachinoides* in Cote d'Ivoire. However, octenol was more attractive for this species when released at lower dose rates (i.e. 0,6–2,0 mg/h). This agrees with the results of Vale & Hall (1985b) in which octenol release rates of 0,5–5,0 mg/h were found best for *G. m. morsitans* and *G. pallidipes*. Higher rates of octenol release (5–500 mg/h) became repellent for the latter two savanna species in Zimbabwe (Vale & Hall 1985a, 1985b). At Hellsgate, on the other hand, no repellency was observed with the increased release rates of octenol.

When added to octenol and 4-methyl phenol, the effect of acetone (350 mg/h) on the attraction of *G. brevipalpis* seemed to be synergistic, especially during the warm and wet season. This finding was supported when acetone, released at *c.* 350 mg/h and added to various doses of octenol and 4-methyl phenol, significantly increased the attraction of this species during April, towards the end of the warm and wet season. This synergistic effect was, however, not found in experiments which were conducted in the dry and cool season when it was shown that the presence of acetone at any release rate (*c.* 0–14 500 mg/h), when added to octenol and 4-methyl phenol, did not increase the catches of *G. brevipalpis* significantly.

High doses of octenol and 4-methyl phenol were ineffective when acetone was absent during the warm and wet season but acted synergistically when it was present during this season and a significant increment in the catches of up to 2,8 times was obtained for *G. brevipalpis* when compared to the Zim-mix. Furthermore the octenol/4-methyl phenol mix, without acetone, was as effective as the Zim-mix in the cool and dry season but was found to be *c.* 2–6 times less effective in the warm and wet season which once again emphasizes the need for acetone in this season. In Kenya acetone was attractive for *G. brevipalpis* albeit at high doses of 2 500 mg/h (Kyorku, Machika, Otiemo & Mwandandu 1995), while no effect was obtained using acetone at 150–200 mg/h in S.E. Kenya (Brightwell & Dransfield 1997). Acetone was also an effective attractant for *G. pallidipes* in Kenya, Zimbabwe and Mozambique, for *G. longipennis* in Kenya and for *G. p. palpalis* in Liberia (Takken 1984; Vale & Hall 1985a, 1985b; Dransfield, Brightwell, Chaudhury, Golder & Tarimo 1986; Cheke & Garms 1988; Kyorku *et al.* 1990).

The present study, therefore, indicated that the role of acetone in the attraction of *G. brevipalpis* could change according to the season. These findings are supported by those of Torr *et al.* (1989) who also found that in Somalia acetone and octenol increased catches of *G. pallidipes* significantly in the wet season, whereas no difference occurred in experiments carried out in the hot dry season. Vale (1974a) also showed that differences in climatic conditions affect odours. The reason for the change in behaviour towards acetone in different seasons in this study is unknown. It is, however, recommended that acetone be used at all times until its mode of action is understood.

The most attractive odour combination for *G. brevipalpis* was thus octenol released at 2,3–9,1 mg/h with 4-methyl phenol released at c. 15,5 mg/h plus acetone released at c. 350 mg/h (i.e. 6 mm diameter aperture). This has proven to be the case in the warm and wet season when these combinations would increase the catches of this species by 2,3–2,8 times when compared to the Zim-mix and 10,1–12,3 times when compared to 'no odour'.

Our studies showed no significant evidence that any of the odours tested were attractive to *G. austeni*. There were no significant differences found following an increase in the release rates of acetone or of the octenol/4-methyl phenol mix, although at high rates (c. 1 500–14 500 mg/h) acetone did have a positive effect on the catches of this species. However, this was not significant and the increase in catches (1,3 fold when compared to the Zim-mix and to 'no odour') does not warrant the inconvenience of its use nor the expense. Owaga (1992) determined that acetone has a depressing effect on *G. austeni* catches in Kenya. Kyorku *et al.* (1995) also found no significant response of this species in Kenya to any of the odours tested. At a later stage Brightwell & Dransfield (1997) showed that acetone and cow urine increased the catches of *G. austeni* males significantly when compared to those of an unbaited trap. In the laboratory Owaga (1992) found a greater response by this species to odour when air was dry (55% R.H.) compared to moist (75–80% relative humidity) and, therefore, concluded that high coastal humidity may have an influence in reducing the effect of odours.

CONCLUSIONS

The present study was restricted to an evaluation of the Zimbabwe synthetic ox-odour mixture and its components for the attraction of *G. brevipalpis* and *G. austeni*.

A very effective attractant combination with optimal release rates could be recommended for *G. brevipalpis*. This consists of octenol released at c. 2,3–

9,1 mg/h plus 4-methyl phenol released at c. 15,5 mg/h with acetone released at c. 350 mg/h. This combination increased the catches of this species by 2,3–2,8 times when compared to the Zim-mix and by 10,1–12,3 times compared to 'no odour'.

Unfortunately, none of the Zim-mix components or combinations attracted *G. austeni*. The present lack of odour attractants for this species, highlights the importance of searching for attractants specific for this species and future efforts should thus focus on this.

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