PERFORMANCE OF PERMANENT AND SUPPLEMENTARY TRAPS FOR MEDITERRANEAN AND QUEENSLAND FRUIT FLIES IN SOUTH AUSTRALIA 1975-2001: COMPARISON OF MALE LURE AND FOOD LURE TRAPS

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Summary

The performance of male lure traps and traps based on food lures were compared using data from trap arrays in South Australia. These traps were used to monitor infestations of the Mediterranean and Queensland fruit flies between 1975 and 2001. For the Mediterranean fruit fly *Ceratitis capitata* (Wiedemann), the efficiency of the food lure traps relative to male lure traps declined when yeast hydrolysate was replaced with yeast autolysate. When the '3-component trap' replaced the yeast-based trap, the situation was essentially restored. Male lure (Capilure) traps caught eight times as many males as 3-component traps, with the latter catching four times as many females as the former. For the Queensland fruit fly *Bactrocera tryoni* (Froggatt), the male lure (cuelure) traps were consistent over time, despite changes in design, but caught very few females. When the food lure traps were based on yeast hydrolysate they caught mainly females (at about a quarter of the rate that the cuelure traps caught males) but they trapped very few flies of either sex after the change to yeast autolysate.

Keywords: *Bactrocera*, *Ceratitis*, traps, cuelure, Capilure, food lure, surveillance

INTRODUCTION

The two main fruit fly (Diptera: Tephritidae) pests in Australia are the Mediterranean fruit fly (Medfly), *Ceratitis capitata* (Wiedemann), and the Queensland fruit fly (Qfly), *Bactrocera tryoni* (Froggatt). Zones that are non-endemic for these species (and also quarantined to exclude them) are designated by international trade agreements as having 'area freedom' from fruit flies. Produce from 'area freedom' zones can be exported without post-harvest treatment for these insects (Anon 1997). One of the requirements for 'area freedom' status is the maintenance of arrays of traps for surveillance and the installation of supplementary traps if flies are detected.

Traps for tephritid fruit flies are of two basic types that use either a lure based on 'food odour' that attracts both sexes (and also some non-target species) or 'male lures' (otherwise termed 'parapheromones') that usually only attract a restricted number of tephritid species (Drew 1982; Cunningham 1989; Jang and Light 1996). Food and male lures cannot be combined in one trap because the latter type impairs the attractiveness of the former (Hill 1986). Food lures are poor attractants when compared with male lures and there is an extensive literature on efforts to improve them (see Jang and Light 1996). The most common food lure contains hydrolysed protein, but recently a '3-component' lure (ammonium acetate, 2-aminobutane and trimethylamine hydrochloride) has been used for Medfly. For about 40 years, the male lures for Qfly and Medfly have been respectively cuelure (4-(3-oxobutyl) phenyl acetate) and trimedlure (TML)(t-butyl-4 (or 5) choro-2-methyl cyclohexane carboxylate). For about the last 20 years TML (which evaporates relatively quickly) has been used either in 'slow-release' dispensers or with 'extenders' in a mixture known as Capilure.

For Qfly, Hooper and Drew (1971), O'Loughlin *et al.* (1983) and Cowley *et al*. (1990) made comparisons of cuelure traps of different designs. Hill (1986) compared cuelure and food lure traps for Qfly (using 45 g/kg active yeast as food lure). She found that the food lure traps caught twice as many males as females but the males were caught at less than 1% of the rate achieved by the cuelure traps (which caught no females).

For Medfly, several comparisons have been made between food lures, between the different ways of using TML and between TML and food lure traps as follows.

Nakagawa *et al.* (1981) and Hill (1987) found that Capilure was as attractive as plain TML in Steiner traps (Steiner 1957) but lasted three times longer (at least 36 weeks). However, Leonhardt *et al.* (1984) and Rice *et al.* (1984) found that plain TML on a cotton wick was more attractive in the first two weeks than it was when used in dispensers or in Capilure on a cotton wick. Wijesuriya and de Lima (1995) compared TML in dispensers with Capilure in both Jackson traps (Harris *et al*. 1971) and Lynfield traps (Cowley *et al*. 1990). They found that results

were similar in a given type of trap but reported that use of dispensers was ten times more expensive than using Capilure on a wick. Hill (1986) compared traps using yeast autolysate with traps baited with Capilure. She found that the yeast-based traps caught males at about 40% of the rate achieved by Capilure traps and females at over 70 times the rate for Capilure traps.

More recently, comparisons have been made of the 'protein' type of food lure for Medfly and the 3-component lure and some have compared the 3-component lure with TML. Bakri *et al.* (1998) found that TML traps caught nearly 20 times more males than 3-component traps but the latter trapped over 90 times more females. Epsky *et al.* (1999) found that the 3-component trap was at least as good at attracting females as traps baited with a mixture of hydrolysed corn protein and borax. However, Katsoyannos *et al.* (1999) reported that the 3-component trap was better at female capture and caught fewer non-target flies. Miranda *et al.* (2001) found the 3-component trap to be equal to the protein trap at female capture and also discovered that adding water to the 3-component trap could increase capture rate but made it more cumbersome to service and less specific (disadvantages shared with the protein trap). Papadopoulos *et al.* (2001) found that the 3-component trap was better than traps with TML early in season but caught less flies than TML traps later.

In South Australia, permanent arrays of male lure traps for both Medfly and Qfly have been established for many decades (Madge *et al*. 1997). When a fly is trapped or larvae are discovered in fruit, equal numbers of food lure and male lure traps are set and the catches are recorded. We therefore have the opportunity to use these records to make comparisons between different types of trap that have been operated simultaneously in populations of low density of both species on real detection and monitoring arrays.

MATERIALS AND METHODS

Trapping of Medfly and Qfly and associated practices in South Australia

Traps for each species are spaced at 400 m intervals in Adelaide and some country towns and at 1 km intervals in fruit production areas. The number of permanent traps in 1975 was 1875 for each species but this number has gradually increased to almost twice that of 1975. For the period 1975-2001, most new detections (only a proportion of which were classed as outbreaks) occurred within the greater Adelaide area (73 out of 93 for Medfly and 259 out of 265 for Qfly). The dates of all catches are recorded, including those of the supplementary traps that are installed in response to a detection by a permanent trap. The response to initial detection is essentially the same for both species.

For Medfly, the trapping of one or more male flies in a given permanent trap triggers the setting of supplementary traps around it and search for larvae is made within the area covered by the supplementary traps. Up to 1998, the supplementary traps consisted of 15 extra male lure traps within a radius of 200 m and 16 traps with a 'lure' based on 'food odour' (food lure traps). Since 1998, the procedure has been different in that a total of 32 extra traps of each kind was installed within 400 m. The trapping of three male flies within the same or adjacent traps within 1 km within 14 days, or the trapping of one female Medfly, or the detection of larvae in fruit triggers the declaration of an outbreak and regulatory measures.

The protocol for Qfly is similar except that supplementary traps are set within a 200 m radius and the trigger for outbreak declaration is five male flies within 1 km within two weeks, or one female or the detection of larvae.

For either species, if larvae are detected without any prior detection of adults supplementary traps are set around the site in addition to the declaration of an outbreak.

Trap types

Illustrations of trap types are given in Drew (1982), O'Loughlin *et al.* (1983), Cowley *et al*. (1990) and Madge *et al.* (1997).

(a) Medfly male lure traps. The active ingredient of the attractant was Trimedlure. The Nadel (Israeli) trap (Nakagawa *et al.* 1971) was deployed up to 1985 when the Jackson trap (Harris *et al*. 1971) was used. This in turn was replaced by the Lynfield trap (Cowley *et al*. 1990) in 1995. Up to 1985, the lure / insecticide mix per trap wick was 5 mL of TML, 10 g/L dichlorvos, renewed once per year. From 1985, the TML was administered in a formulation with extenders as known as Capilure and renewed five times per year.

(b) Medfly food lure traps. Up to 1998, glass invaginated traps (McPhail 1937) were deployed using a liquid lure without insecticide. Until 1983, the lure was a 200 mL aqueous mixture of protein (yeast) hydrolysate (20g/kg), vanillin (1.2g/kg) and

ammonium chloride (5g/kg). From 1983 to 1998, yeast autolysate was used instead of yeast hydrolysate. The mix was replaced twice per week. From 1998, a 3-component lure was used in plastic trap based on the McPhail design but with a detachable base. The three components of the lure (BioLure® supplied by Consep Inc, Oregon) are in separate sachets that can be fixed to the inside of the trap. The three components are ammonium acetate, 2-aminobutane (putrescine) and trimethylamine hydrochloride and together with a small piece (10 mm x 12 mm) of dichlorvos impregnated 'pest strip' are replaced every 4-6 weeks.

(c) Qfly male lure traps. The attractant used was cuelure. Up to 1979, Bateman traps (Hooper and Drew 1971) were deployed, then Steiner traps (Steiner 1957) in a modified 'Queensland version' (Hooper and Drew 1971) until 1985. Jackson traps were used from 1985 to 1990 and Lynfield traps from 1991. Up to 1978, the lure / insecticide mix was applied as an alcoholic solution but as the alcohol evaporated the remainder was effectively a 1.0 mL cuelure / malathion mixture at a ratio of 5:1. From 1979, 5 mL of the mix was applied without alcohol at a ratio of 8:1. The lure mixture was replaced twice a year except from 1979 to 1984 when it was replaced only once a year.

(d) Qfly food lure traps. These were the same as the yeast-based traps for Medfly, except that their use has continued to the present.

Comparison of trap performance

Two methods of comparison were used. The first compared the mean catch per infestation for each type of trap during certain periods of interest. The second method was to find, for the same periods of interest, the percentage of the total catch that was caught by each type of trap. For the latter calculations, we could only use data from those infestations that were monitored by both permanent and supplementary traps and further restrict data to that pertaining to catches made when all the traps were set simultaneously.

For Medfly, the periods of interest were those pertaining to the use in the food-based traps of yeast hydrolysate, yeast autolysate or the 3-component satchels and in the male lure traps of plain TML or Capilure. Choice of periods was constrained to an extent by the requirement to have enough observations (n) for sufficient precision. Thus we chose the following periods, (a) 1975-1980 (when the chief food lure component was yeast hydrolysate and the male lure was TML alone), n= 6; (b) 1981-1985 (when similar conditions applied except that the last five observations involved the use of food lure traps with yeast autolysate), n 20; (c) 1986-1997 (when food lure traps had yeast autolysate and Capilure replaced plain TML), n=22; (d) 1998-2001 (when the yeast-based food lure traps were replaced with the 3-component traps, (n=34).

For Qfly, the periods were kept the same except there were sufficient observations to split the second period into two (pertaining to the use in the food lure traps of yeast hydrolysate and yeast autolysate in the first and second parts respectively). There were thus five periods for Qfly having n values of 38, 20, 30, 157 and 20 respectively. For the purposes of comparing percentages of catches, the number of pertinent infestations in each period of interest were restricted (as explained above) and numbered 12, 13, 13 and 11 respectively for Medfly and 16, 4, 5, 17 and 5 for Qfly.

The statistical significance of rises or falls in catch per infestation or percentage of total catch were assessed by paired comparisons pertinent to independent samples from normal and binomial distributions respectively, using a significance levels of p=0.05 and 0.01 respectively (Snedecor and Cochran 1980).

RESULTS

The results of Medfly trapping in four periods are shown in Figure 1. The upper graph shows the catch of males and females per infestation per type of trap. The traps were respectively male lure ('dry') and alternative (yeast based or 3-component). The lower graph is in terms of percentage of total catch for the relevant periods when both types of trap were set simultaneously. In the latter circumstances, male lure traps respectively caught only 50.7 and 50.9 % of the flies in the first two periods with very few being female. This rose to 90.1 % in the third period and fell back to 71.0 % in the fourth. The alternative traps caught more females than males.

The average catch per infestation was higher in the first period but there was no statistically significant trend with time except for the collapse of the 'alternative' catch in the third period, which was significant in terms of both catch per infestation and percentage of catch. The corresponding rise in percentage catch by the dry traps was the converse of the foregoing and is not reflected in any significant rise in catch per infestation.

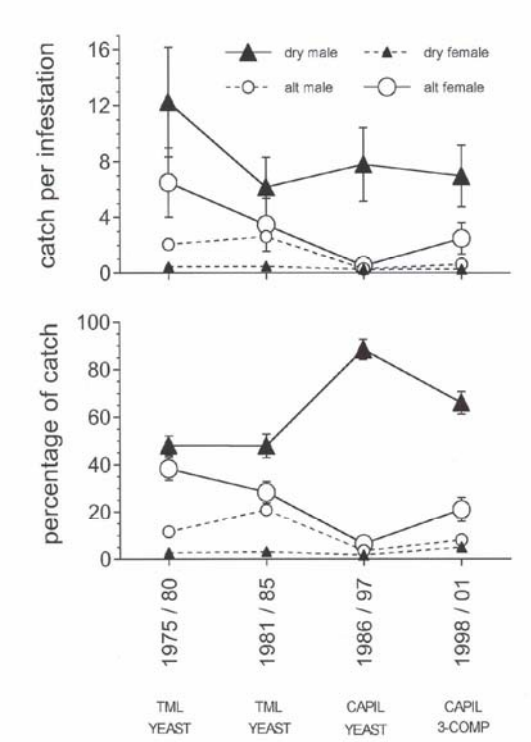

Figure 1. Trends in Medfly captures with male-lure ('dry') traps and alternative ('alt') traps. The lure in the dry traps in the first and last two periods was plain trimedlure (TML) and Capilure (CAPIL) respectively. The design of the dry traps was Nadel for the first two periods, Jackson to 1995 in the third and Lynfield from 1996 and in the fourth. The lure in the alternative (McPhail) traps contained yeast hydrolysate in the first and most of the second period and yeast autolysate in the third. The 3-component lure (in modified McPhail traps) was used in the fourth period. Upper graph, means ± SE, *n* = (L to R) 16, 20, 22, and 34. Lower graph, ± binomial SE, *n*= (L to R) 277, 159, 173, 157 and 100.

The results of Qfly trapping in five periods are shown in Figure 2, which has an analogous format to Figure 1. Again, we can see a higher catch per infestation in the first period. The upper graph shows that most catches were overwhelmingly males in male lure traps. The lower graph is for data pertaining to times when both types of trap were set. Even here, the male catch in male lure traps predominated, with the female catch in the alternative traps being a little over a quarter of that in the first two periods but declining to very small proportions thereafter. There were almost no females trapped in male-targeted traps and almost no males in the alternative traps.

DISCUSSION

Although a comparison of percentages gave us the clearest contrasts, a decline in the percentage caught by one type of trap (the alternative trap) may appear to cause a corresponding rise in another (catch by a male lure trap) but we will never know if the reverse causality was the case. If the percentage share of the total catch by each kind of trap always remained the same, our plots of catch per infestation should go up and down together. This is not apparent in either of our figures, indicating that, for both species, the performance of the different types of trap was changing over time. The best indication of which type was changing is given when both catch per infestation and percentage share of the total catch are seen to change relative to the other data. Using this criterion, we can conclude that our data show (for both Medfly and Qfly) that the performance of the male lure traps was consistent over time regardless of changes in either lure formulation or the physical design of the trap. We can also conclude that the efficiency of the food lure traps for both species declined when yeast hydrolysate was replaced with yeast autolysate and that, in the case of Medfly, efficiency was largely restored when the 3-component trap replaced the one based on yeast autolysate.

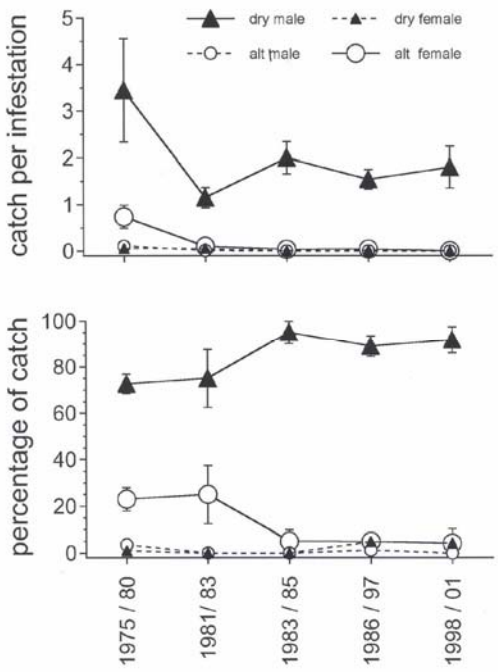

Figure 2. Trends in Qfly captures with male-targeted ('dry') traps and alternative ('alt') traps. The lure in the dry traps was cuelure in all periods. The design of the dry traps was Bateman in the first period (except 1980), Steiner (modified) in the second and third, Jackson to 1995 in the fourth and Lynfield from 1996 and in the fifth. The lure in the alternative (McPhail) traps contained yeast hydrolysate in the first two periods yeast autolysate in the others. Upper graph, means ± SE, *n* = (L to R) 38, 20, 30, 157 and 20. Lower graph, ± binomial SE, *n* = (L to R) 113, 12, 20, 82 and 13.

For Medfly, we can say that our results pertaining to when yeast hydrolysate was used are approximately equivalent to the results of Hill (1986) who used yeast autolysate as food lure. However, our results for food lure when it was based on yeast autolysate are very poor in comparison. Bakri *et al.* (1998) found that TML traps caught nearly 20 times more males than 3-component traps but the latter trapped over 90 times as many females. We have not found such a great contrast. Our Capilure traps caught only eight times as many males as 3-component traps and the latter caught only four times as many females as the former. Recent investigations have found that traps with the 3-component lure to be as good as or better than traps baited with a mixture of hydrolysed corn protein and borax (Epsky *et al.* 1999; Katsoyannos *et al.* 1999; Miranda *et al.* 2001). Our data do not allow us to compare the protein and 3-component traps directly. However, if we compare performance against male lure traps, we can say that the 3-component traps are greatly superior to alternative traps based on yeast autolysate but possibly not as good as the traps that were based on yeast hydrolysate during the first period pertinent to our study (1975-1980).

For Qfly, Hill (1986) compared cuelure traps and food lure traps. She used a suspension of active yeast in the latter and showed that they achieved very poor results (in contrast to the performance achieved with the bait she used for Medfly). Her results with Qfly were very similar to the ones reported here that pertain to the period of use of yeast autolysate. Hooper and Drew (1971), O'Loughlin *et al.* (1983) and Cowley *et al.* (1990) made comparisons of cuelure traps of different designs. The first of these papers found that the modified Steiner trap was more efficient than the Bateman trap, the second found that the Jackson trap was better than the Steiner and the third found that the Lynfield trap was more efficient than the Jackson trap. These conclusions were based on direct comparisons that would have been more sensitive than those available to us. However, our data is quite sufficient to reveal the dramatic decline in the absolute and relative efficiency of the food lure traps that can be associated with the change from yeast hydrolysate to yeast autolysate. It appears that the food lure traps of the type that is presently used in South Australia for Qfly have almost no utility.

Unfortunately, we do not know what it was about the early yeast hydrolysate that made it appear to work better. It is possible that yeast autolysate (now used only in Qfly traps) is too acidic. Jang and Light (1996) refer to literature showing that protein hydrolysate is more effective if basified.

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