REVIEW OF THE USE OF PROTEIN FOOD BASED LURES IN MCPHAIL TRAPS FOR MONITORING QUEENSLAND FRUIT FLY *BACTROCERA TRYONI* (FROGGATT) (DIPTERA: TEPHRITIDAE)

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Summary

A literature review reveals many undesirable features of wet protein food baited McPhail traps including the cost to service these traps, their short distance of attraction, their short period of attraction, and their capacity to attract non-target insects. There are other possible concerns which may alter the attraction of wet protein foods such as the role of bacteria and chemical aspects including pH and salinity. There is little data to support the continued use of wet protein baited McPhail traps as specialist traps for female Queensland fruit fly.

Keywords: autolysate, hydrolysate, protein, monitoring, surveillance, *Bactrocera*

EARLY HISTORY OF FRUIT FLY BAITS FOR MONITORING AND SPRAYS

The ability to trap Queensland fruit fly (Qfly) *Bactrocra tryoni* (Froggatt) (Diptera:Tephritidae) has been fundamental to programs aimed at monitoring the pest's progressive spread across eastern Australia (May 1963). There was, and still is, a strong desire to attract female Qfly, as females lay eggs which spoil fruit and subsequently compromise trade. Gurney (1925) reported on a new trap for Qfly which subsequently evolved into the McPhail trap. The effectiveness of early trap lures was mixed with at least one only attractive to fruit flies after fruit had become infested (Jarvis 1925). Lures tested included molasses (Jarvis 1926) and a mixture of vanilla essence and ammonia (Jarvis' lure) which appeared to be equally attractive for both sexes of Qfly (Jarvis 1931).

The use of ammonia or protein based attractants for bait sprays has been reported in much more detail and more frequently than for use in monitoring traps. Ammonia was first reported as being an attractant for Qfly in the 1930s (Jarvis 1931, Perkins and Hines 1934) with weak solutions being most effective (Veitch 1934). However ammonia based lures were relatively short-lived and many ammonia based mixtures were developed to extend its usefulness. Mixtures trialled included essence of vanilla and household ammonia (Anon. 1937, Allman 1941), rock ammonia (ammonium carbonate), pulped orange (May 1958), and the use of sugar bait with 1% urea (Allman 1958).

The use of protein based baits was recommended by McPhail (1939) and subsequently protein hydrolysate was suggested by Gow (1954) as a longer lasting ammonia-producing food lure. Protein hydrolysate is manufactured by adding hydrochloric acid to plant or animal protein; the destruction of protein cells releases ammonia and other volatiles. The use of hydrochloric acid in the production of protein hydrolysate results in a liquid protein bait with an acid or low pH. Excess acid is neutralised by adding sodium hydroxide but results in a salt residue in the bait. Products with a salt content ranging from 6% to 18% caused burning of fruit and foliage (Sproule 1975, Bateman 1978, Allwood 1997, Smith and Nannan 1988, Anon. 2002). Despite this, protein hydrolysate was developed in Australia during the 1950s and was widely used by the early 1960s (Sproule 1975). Hely (1960) reported protein hydrolysate caused foliage damage and fruit marking with the most attractive compounds causing the greatest phyto-toxicity. Phyto-toxicity was minimised by the use of splash baits (Allwood 1997) rather than a spray. The phyto-toxicity of protein hydrolysate bait sprays were largely overcome by the development of autolysate formulations in the mid 1980s (Allwood 1997). Protein autolysate is produced by enzymatic autolysis of protein with yeast as the most common source of protein. This process results is less acidity and less salt, compared with acid hydrolysis of protein (Lloyd and Drew 1997).

Between 1984 and 1993, both protein hydrolysate and autolysed yeast were considered suitable for bait spraying (Keenan 1984, Thwaite *et al.* 1992) however in 1995 only protein autolysate was recommended (Thwaite *et al.* 1994). In 1997, both products were again in favour (Thwaite and Penrose 1997) but by 2004, only autolysate was recommended (Hetherington *et al.* 2004). Protein autolysate bait spray has been used in the Torres Strait for at least ten years (Huxham 2002), and protein hydrolysate was supported in the Northern Territory (Smith 1992), and in Victoria (East 1982).

Wet protein food baits have the reputation of being specialist lures for female Qfly. Unfortunately there is very limited published data on the attractiveness in the field of the liquid protein typically used in traps. This paper reviews the use of protein based food lures as an attractant for use primarily in surveillance traps in an attempt to review McPhail trap use for Qfly. Protein bait spray information is also reviewed to provide additional information.

ROLE OF PROTEIN IN THE BIOLOGY OF TEPHRITID FRUIT FLIES

The reasons behind the reputation of protein being a specialist female attractant are unclear. Many authors indicated that both adult male and female Qfly required protein in their diet to reach sexual maturity (Bateman 1972, Fletcher 1987, Keenan 1984, Vickers 1999, Hetherington *et al.* 2004). Drew (1987) reported that male Qfly required little or no protein to fertilize eggs whereas females required at least one protein feed to ensure egg production. Meats and Leighton (2004) found that female Qfly require more than 0.1 mg of yeast autolysate per day to mature their oocytes. There is no overwhelming evidence indicating that protein foods have a special attraction for female Qfly only.

Drew (1987) found slightly more female Qfly died after 28 days of protein starvation and a similar trend was seen when flies were fed protein and sugar for the same period. Miller *et al.* (2004) and Lloyd *et al.* (2000) noted that proteinaceous foods were particularly effective at luring protein hungry flies but less effective if flies could find alternative protein sources such as bird faeces.

The odour of yeast hydrolysate increased the frequency of flight in immature female Qfly but mature females previously fed on hydrolysate did not have increased flight frequency. The flight activity of mature males increased in the presence of the odour of the synthetic pheromone cue-lure (Dalby-Ball and Meats 2000).

Raghu (2004) indicated that male flies were mainly driven by olfactory cues whereas females used both olfactory and visual cues. This may explain why it has been generally so difficult to find an effective female attractant and trap. Sproule (1975) reported the development of male attractant cue-lure was vastly more effective as a male attractant than protein food lures. Cue-lure was a very effective lure for Qfly males, and it was assumed that there was an expectation that a similarly effective lure for females would be developed. Perhaps because this did not occur, protein food lures subsequently developed a reputation as female lures.

EFFECTIVENESS IN TRAPPING FEMALE FRUIT FLIES

Given that protein traps were reputed to attract female Qfly, it is presumably why the use of wet protein food based McPhail traps was a condition of trade agreements (Anon. 1997). Protein hydrolysate was reported to catch more female than male Qfly (Drew and Hooper 1981, Vickers 1999, Meats *et al.* 2002). Matthews (1996) noted that bait traps caught female flies and assisted scientists to determine population size. When using protein autolysate, Vickers (1999) trapped more female Qfly than males however baited trees attracted 3131 flies while traps collected only 472 flies. Trial results lacked consistency. Some researchers reported protein hydrolysate McPhail traps caught about equal numbers of male and female Qfly (O'Loughlin 1983, Hetherington *et al.* 2004, Weldon 2005) whereas Hill (1986) reported that yeast traps caught twice as many males as female Qfly and Meats *et al.* (2002) found that yeast autolysate caught very few of either sex.

Chapman (1982) noted that Qfly females had a lesser flight capacity than males and that this was in contrast to most other species. If this is the case, food lure traps used over a broad area (even 200 m radius) are unlikely to trap more females than males unless they are close to the emergence point. The lesser flight capacity of female Qfly is likely to reduce the effectiveness of protein based McPhail traps unless they are placed very near to trees infested by female Qfly.

Gow (1954) and Anon. (1997) indicated that protein McPhail traps should be used in the warmer months because the attraction to protein appeared to be substantially reduced in winter months. Also, wet protein food lures rapidly lose their attraction to Qfly (Keenan 1984, Vickers 1999, Smith and Nannan 1988) declining significantly after the first day. Gels have been added to bait sprays in an attempt to prevent rapid drying and hence to minimise the associated decrease in attraction (Bull 2002). Prokopy *et al.* (1993) and Bateman (1972) found bird faeces were much more attractive to tephritids than fresh protein bait.

There are many papers indicating that cue-lure Lynfield traps are more effective for male Qfly than food lure traps (Fletcher 1974, Sproule 1975, Meats *et al.* 2002, Lloyd *et al.* 2000, Dominiak *et al.* 2003, Weldon 2005) with some claiming McPhail traps were of questionable value particularly when population density was low (Drew 1978, Yeates *et al.* 1992, Matthews 1996, Anon. 1997).

It seems likely that the reputation of protein as a specialist lure for female Qfly is undeserved.

SHORT COMINGS OF PROTEIN TRAPS

Range

Cue-lure is attractive for up to about 60 metres (Allman 1958). By comparison, protein traps are reported to be attractive over no more than several metres (Eisemann 1980), at least five metres (Bateman 1978), or 12 metres (Creevy 1989). Bateman and Morton (1981) indicated the great volatility of ammonia was the reason for its apparently feeble active range. Weldon (2005) commented that recaptures of Qfly using yeast autolysate declined rapidly from the release point. Trap spacings would need to be much closer than for cue-lure Lynfield traps if used for monitoring purposes.

This short distance appears to be recognised in bait programs which required the application of 100 mL of bait on every second tree in every second row (Thwaite *et al.* 1992). Bateman (1978) and Keenan (1984) indicated that spots of bait should be 20 metres apart. This short distance may account for the comparatively high variability in the trap catches of McPhail traps, compared with the perceived long attraction distance of cue-lure. Keenan (1984) indicated that fruit flies may be attracted reasonable distances to bait, but that air currents played an important role. Clearly, traps should be placed as close as possible to likely infestations but if the McPhail traps are being used to locate infestations, it is fundamental to know how far they can attract Qfly.

Costs

McPhail traps are expensive, time consuming and of limited value for detection work compared with pheromone based traps (Drew 1978, Fletcher 1974, Matthews 1996, Dominiak *et al.* 2003). Sproule *et al.* (2001) reported that wet traps were cumbersome, the contents were easily spilled when the trap was handled, and removal of insects was time consuming and tedious.

The McPhail trap and lure cost thirteen times more than the Lynfield trap (Broughton and de Lima 2002). The International Atomic Energy Agency (IAEA) (2003) noted that liquid traps take at least twice as long to service as other types of traps. They also become less attractive over time as the pH changes. Protein solutions should be changed twice weekly (Grove *et al.* 2002) to avoid loss of liquid due to spillage (Anon. 1997), evaporation (Fletcher 1974, Anon. 1997) or decomposition of the flies (Hill 1986, Anon. 1997, Sproule *et al.* 2001). In an attempt to minimise decomposition, borax has been added (Yeates *et al.* 1992) however bait attractancy decreased (Duyck *et al.* 2002, Nigg *et al.* 2002).

The requirement for twice weekly replacement of protein lures in McPhail traps compares poorly to the six monthly replacement schedule of cue-lure (Anon. 1997, Dominiak *et al.* 2003). Similarly cue-lure traps are inspected weekly while McPhail traps need to be inspected twice weekly (Anon. 1997). Jang and Light (1996) and Nigg *et al.* (2002) reported that most agencies preferred dry traps over water-based traps due to their relative ease in servicing, and retrieval of flies.

Non-target species

Sproule *et al.* (2001) reported that wet traps attracted non-target species such as ferment flies, blowflies, grasshoppers and cockroaches. Dominiak *et al.* (2003) reported that McPhail traps caught 38 times as many Island fly (*Dirioxa pornia* Walker) than Qfly. Trapping of non-target insects has also been reported by IAEA (2003), Thomas (2003), Gopaul *et al.* (2000), Stravens *et al.* (2000) and Hallman and Schwalbe (2002). These non-target trappings add to the labour requirements to service McPhail traps. Cue-lure traps do not have this additional burden.

Salinity and acidity

Salinity is a by-product of the acid hydrolysis of protein and while it causes phyto-toxicity as a spray, it appears to have little impact in the McPhail trap. The salt problem was partly overcome by using enzymatic autolysis however Meats *et al.* (2002) indicated that autolysate preparations were less attractive than protein hydrolysates.

Acidity alters some characteristics. Bateman and Morton (1981) found that protein hydrolysate has a pH of 4.8, and that they could increase the mean attraction by changing the pH to 8.5. Allwood (1997) indicated the pH of yeast autolysates were higher than the pH of acid hydrolysates. Salinity and pH may also affect the role of bacteria.

The attraction of proteinaceous materials appeared to be chiefly due to products resulting from microbial action however there is a diversity of opinion. Gow (1954) concluded the bacterium *Proteus* sp. was responsible for the attraction of protein hydrolysate mixtures. Steiner (1955) reported the addition of fungicides destroyed or reduced the effectiveness of protein hydrolysate. Fitt and O'Brien (1985) reported a wide diversity of bacteria found in four species of *Dacus,* and an apparent lack of consistent species of bacteria being associated with a particular fruit fly species. Drew *et al.* (1983) found various leaf-inhabiting bacteria (Enterobacteriacae) produced attractant materials for fruit flies and contributed to the abundance of fruit flies in nature. They suggested that the acidity of adult fruit fly gut was sufficient to autolyze the ingested bacteria to provide proteinaceous nutrition.

Allwood (1997) postulated that autolysates were more attractive than hydrolysates to fruit flies because the salt in hydrolysates inhibited the development of naturally occurring bacteria. Drew *et al.* (1983) commented that there was no hydrolysed protein in nature and implied that the use of hydrolysed protein could be flawed. The attractiveness of wet protein traps could be enhanced by the addition of naturally occurring bacteria. Aluja *et al.* (2001) reported *Anastrepha* sp. harbours a different microflora in the gut compared with those reported by Courtice and Drew (1983). It has been suggested (Allman 1958) that the addition of sugar increases the attractiveness of protein baits. Perhaps the sugar offers an energy substrate for bacterial growth.

Interference - difficulties with two types of traps close together

Under the requirements of the Code of Practice (Anon. 1997), both wet protein food McPhail traps and cue-lure Lynfield traps should be deployed in close proximity in an attempt to locate the epicentre of an incursion. There has been some concern that protein lures in close proximity to cue-lure may be counter productive. Hill (1986) reported that when a cue-lure wick was suspended just above the yeast solution, the number of female Qfly dropped to 6.6% of the number trapped in yeast solutions alone. Hill suggested that repellent action of male lures was strong enough to almost entirely counteract the attractive properties of protein bait for Qfly females. Presumably as a result of Hill's work, the trade protocol (Anon. 1997) stipulates that McPhail traps should be three to four metres from Lynfield traps.

CONCLUSION

Contrary to previous expectations, there appears to be little data to support the use of protein autolysate or hydrolysate McPhail traps as specialist traps for female Qfly. This reputation as a specialist female Qfly lure may be based on reports that females require protein for sexual development, and that males do not. This review suggests that protein food baits are of very limited value as lures for Qfly. It is increasingly difficult to support the continued use of protein food McPhail traps as early warning or monitoring devices for Qfly due to the cost to service these traps, their short distance of attraction, the short period for which they are attractive, and their capacity to attract non-target insects. Currently there is research in eastern Australia to find a dry attractant for female Qfly, or to otherwise improve the efficiency of wet protein lures.

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REFERENCES

Allman, S.L. (1941). Control of Queensland Fruit Fly Caged tree tests. *The Agricultural Gazette of New South Wales* **52:** 281-282.

Allman, S.L. (1958). Queensland fruit fly. New South Wales Department of Agriculture. In: *Conference of Commonwealth and State Entomologists*. Brisbane, May 1957. Commonwealth Scientific and Industrial Research Organisation. 68-70.

Allwood, A.J. (1997). Control strategies for fruit flies (family Tephritidae) in the South Pacific. In: Allwood, A.J. and Drew, R.A.I. *Fruit fly management in the Pacific*. ACIAR Proceedings no. 76. 171-178.

Aluja, M., Jacome, I. and Macias-Ordonez, R. (2001). Effect of adult nutrition on male sexual performance in four Neotropical fruit fly species of the genus *Anastrepha* (Diptera: Tephritidae). *Journal of Insect Behaviour* **14**: 759-775.

Anon. (1937). Insect pests and their control. *The Agricultural Gazette of New South Wales* **48:** 460-464.

Anon. (1997). *Code of Practice for the management of Queensland Fruit Fly.* Standing Committee on Agriculture and Resource Management, Department of Primary Industries, Canberra.

Anon. (2002). Protein bait sprays for control of fruit flies. http://www.spc.int/pacifly/control/bait_spraying_1.htm

Bateman, M.A. (1972). The ecology of fruit flies. *Annual Review of Entomology* **17**: 493-518.

Bateman, M.A. (1978). Chemical methods of suppression or eradication of fruit fly populations. In: Drew, R.A.I., Hooper, G.H.S., and Bateman, M.A. (Eds.) *Economic Fruit flies of the south Pacific Region*. Watson Ferguson, Brisbane, 111-125.

Bateman, M.A. and Morton, T.C. (1981). The importance of ammonia in proteinaceous attractants for fruit flies (Family: Tephritidae). *Australian Journal of Agricultural Research* **32**: 883-903.

Broughton, S. and de Lima, C.P.F. (2002). Field evaluation of female attractants for monitoring *Ceratitis capitata* (Diptera: Tephritidae) under a range of climatic conditions and population levels in Western Australia. *Journal of Economic Entomology* **95**: 507-512.

Bull, R.M. (2002). Control of tephritid fruit flies in Australian stone fruit crops using low-dose fipronil bait sprays. *Proceedings of the 6th International Fruit Fly Symposium,* 6-10 May 2002, Stellenbosch, South Africa. 301-304.

Chapman, M.G. (1982). Experimental analysis of the pattern of tethered flight in the Queensland fruit fly *Dacus tryoni. Physiological Entomology* 7: 143-150.

Courtice, A.C. and Drew, R.A.I. (1983). New Attractant for fruit flies. *HortScience* **18:** 805.

Creevy, H. (1989). Fruit fly control – backyard requirements. *News* NSW Agriculture. 2pp.

Dalby-Ball, G. and Meats, A. (2000). Influence of the odour of fruit, yeast and cue-lure on the flight activity of Queensland fruit fly, *Bactrocera tryoni* (Froggatt) (Diptera: Tephritidae). *Australian Journal of Entomology* **39:** 195-200.

Dominiak, B.C., Gilmour, A.R., Kerruish, B. and Whitehead, D. (2003). Detecting low populations of Queensland fruit fly *Bactrocera tryoni* (Froggatt) with McPhail and Lynfield traps. *General and Applied Entomology* **32:** 49-53.

Drew, R.A.I. (1978). Fruit fly collection. In: Drew, R.A.I., Hooper, G.H.S., and Bateman, M.A. (Eds.) *Economic Fruit flies of the south Pacific Region*. Watson Ferguson, Brisbane. 129-139.

Drew, R.A.I. and Hooper, G.H.S. (1981). The responses of fruit fly species (Diptera: Tephritidae) in Australia to various attractants. *Journal of the Australian Entomological Society* **20:** 201-205.

Drew, R.A.I., Courtice, A.C. and Teakle, D.S. (1983). Bacteria as a natural source of food for adult fruit flies (Diptera: Tephritidae). *Oecologia* **60**: 279-284.

Drew, R.A.I. (1987). Behavioural strategies of fruit flies of the genus *Dacus* (Diptera: Tephritidae) significant in mating and host-plant relationships. *Bulletin of Entomological Research* 77**:** 73-81.

Duyck, P.F., Quillici, S., Fabre, F. and Ryckewaert, P. (2002). Comparison and optimisation of the efficiency of different food attractants for both sexes of the melon fly, *Bactrocera cucurbitae* (Coquillett) (Diptera: Tephritidae). *Proceedings of the 6th International Fruit Fly Symposium,* 6-10 May 2002, Stellenbosch, South Africa. 351-354.

East, R. (1982). Queensland fruit fly in Victoria. Agnote 1831/82. Government of Victoria.

Eisemann, C.H. (1980). An investigation of some stimuli influencing host finding and oviposition behaviours of the Queensland fruit fly *Dacus (Bactrocera) tryon*i (Frogg.). Masters Thesis. University of Queensland, Brisbane, Australia. 206pp.

Fitt, G.P. and O'Brien, R.W. (1985). Bacteria associated with four species of *Dacus* (Diptera: Tephritidae) and their role in the nutrition of the larvae. *Oecologia* **67**: 447-454.

Fletcher, B.S. (1974). The ecology of a natural population of the Queensland Fruit Fly, *Dacus tryoni* V. The dispersal of Adults. *Australian Journal of Zoology* **22**: 189-2002.

Fletcher, B.S. (1987). The biology of Dacine fruit flies. *Annual Review of Entomology* **32:** 115-144.

Gow, P.L. (1954). Proteinaceous baits for the Oriental Fruit Fly. *Journal of Economic Entomology* **47:** 153-160.

Gopaul, S., Price, N.S., Soonoo, R., Stonehouse, J. and Stravens, R. (2000). Technologies of fruit fly monitoring and control in the Indian Ocean region. In Price, N.S. (Eds.). *Indian Ocean Commission European Union.* 1-17.

Grove, T., Steyn, W.P. and De Beer, M.S. (2002). Fruit flies associated with litchi production in South Africa. *Proceedings of the 6th International Fruit Fly Symposium,* 6-10 May 2002, Stellenbosch, South Africa. 313-316.

Gurney, W.B. (1925). The control of fruit fly. *The Agricultural Gazette of New South Wales* **36**: 879.

Hallman, G.J. and Schwalbe, C.P. (2002). *Invasive arthropods in agriculture – problems and solutions*. Science Publishers Inc., Enfield, New Hampshire, USA.

Hely, P.C. (1960). Fruit fly research: review of progress and plans for future work. New South Wales Department of Agriculture. In: *Conference of Commonwealth and State Entomologists*. Adelaide, October 1959. Commonwealth Scientific and Industrial Research Organisation. 7-10.

Hetherington, S.D, Bright, J.D. and Thwaite, W.G. (2004). 2004/05 Orchard plant protection guide for deciduous fruits in NSW. NSW Department of Primary Industries. 109-111.

Hill, A.R. (1986). Reduction in trap captures of female fruit flies (Diptera: Tephritidae) when synthetic male lures are added. *Journal of the Australian Entomological Society* **25:** 211-214.

Huxham, K.A. (2002). A unique fruit fly monitoring and control system – Australia's frontline of northern defence. *Proceedings of the 6th International Fruit Fly Symposium,* 6-10 May 2002, Stellenbosch, South Africa. 331-334.

International Atomic Energy Agency (2003). Trapping guidelines for area-wide fruit fly programmes. International Atomic Energy Agency, Vienna. 47pp.

Jang, E.B. and Light, D.M. (1996). Olfactory semichemicals of Tephritids. In: McPheron B.A. and Steck, G.J (Eds.). *Fruit fly Pests – A world assessment of their biology and management.* St Lucie Press.

Jarvis, H. (1925). The fruit fly – report on measures of possible control, 1924-25. *Queensland Agricultural Journal* **24**: 48-52.

Jarvis, H. (1926). The Queensland Fruit fly *(Chaetodacus tryoni* Froggatt). *Queensland Agricultural Journal* **26**: 101-104.

Jarvis, H. (1931). Experiments with a new fruit fly lure. *Queensland Agricultural Journal* **36**: 485-491.

Keenan, P. (1984). Queensland fruit fly and its control. Department of Agriculture, New South Wales. 12pp.

Lloyd, A. and Drew, R.A.I. (1997). Modification and testing of brewery waste yeast as a protein source for fruit fly bait. In: Allwood, A.J. and Drew, R.A.I. (Eds.) *Fruit fly management in the Pacific*. ACIAR Proceedings No 76: 171-178.

Lloyd, A., Hamacek, E., Smith, D. and Kopittke, R. (2000). Evaluation of protein bait spraying and inspection on the packing line as quarantine treatments for fruit fly in citrus. Final Report. HRDC Project CT97036. Horticultural Research and Development Corporation. 55pp.

McPhail, M. (1939). Protein lures for fruit flies. *Journal of Economic Entomology* 35: 485-491.

Matthews, C. (1996). Enemy number one – the fruit fly. *The Orchardist* **1**: 10-13.

May, A.W.S. (1958). Fruit fly problem in southern and central Queensland. *Queensland Agricultural Journal* **84:** 153-159.

May, A.W.S. (1963). An investigation of fruit flies (Trypetidae: Diptera) in Queensland. *Queensland Journal of Agricultural Science* **20:** 1-82.

Meats, A. and Leighton, S.M. (2004). Protein consumption by mated, unmated, sterile and fertile adults of the Queensland fruit fly, *Bactrocera tryon*i and its relation to egg production. *Physiological Entomomology* **29:** 176-182.

Meats, A., Clift, A.D., and Perepelicia, N. (2002). 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. *General and Applied Entomology* **31:** 53-58.

Miller, N.W., Vargas, R.I., Prokopy, R.J. and Mackay, B.E. (2004). State-dependent attractiveness of protein bait and host fruit odor to *Bactrocera cucurbitae* (Diptera: Tephritidae) females. *Annals of the Entomological Society of America* **97:** 1063-1068.

Nigg, H.N., Simpson, S.E., Schumann, R.A., Exteberria, E. and Jang, E.B. (2002). Kairomones for the management of *Anastrepha* spp. fruit flies. *Proceedings of the 6th International Fruit Fly Symposium,* 6-10 May 2002, Stellenbosch, South Africa. 335-347.

O'Loughlin, G.T. (1983). Queensland fruit fly in Victoria – a synopsis of observations on its biology and control. Research Project Series No. 177. Department of Agriculture, Victoria. 71pp.

Perkins, F.A. and Hines, H.J. (1934). A note on some preliminary experiments with ammonia as a lure for Queensland fruit fly (*Chaetodacus tryoni* Frogg). *Royal Society Queensland Proceedings* **45**: 29.

Prokopy, R.J., Cooley, S.S., Garlaza, L. and Bergweiler, C. (1993). Birds droppings compete with bait sprays for *Rhagoletis pomonella* (Walsh) flies (Diptera: Tephritidae). *Canadian Entomologist* **125:** 413-422.

Raghu, S. (2004). Functional significance of phytochemical lures to dacine fruit flies (Diptera: Tephritidae): an ecological and evolutionary synthesis. *Bulletin of Entomological Research* **94:** 385-399.

Smith, E.S.C. (1992). Control of fruit fly by commercial producers of fruit and vegetables. Agdex No. 622. No 19. 4pp.

Smith, D. and Nannan, L. (1988). Yeast autolysate bait sprays for control of Queensland fruit fly on passion fruit in Queensland. *Queensland Journal of Agricultural and Animal Sciences* **45:** 169-177.

Sproule, R.S. (1975). Queensland fruit fly – south western region.

NSW Department of Agriculture. 52pp.

Sproule, A., Broughton, S., De Lima, F., Hardie, D., Monzu, N. and Woods, W. (2001). The fight against fruit flies in Western Australia. Department of Agriculture, Perth, Western Australia. Bulletin No 4504. 74pp.

Stravens, R., Gopaul, S., Fowler, S.V. and Stonehouse, J.M. (2000). Experimental evaluation of fruit fly assessment and control methods in Seychelles. *Proceedings of the Indian Ocean Commission Regional Fruit Fly Symposium,* 5th–9th June 2000, Mauritius. 49-53.

Steiner, L.F. (1955). Bait sprays for fruit fly control. *Agricultural Chemistry* **10:** 32-43.

Thomas, D.B. (2003). Nontarget insects captured in fruit fly (Diptera: Tephritidae) surveillance traps. *Journal of Economic Entomology* **96**: 1732-1737.

Thwaite, W.G., and Penrose, L.J. (1997). 1997/98 Orchard plant protection guide for inland New South Wales. NSW Agriculture. 30-31.

Thwaite, W.G., Penrose, L.J., Wickson, R.J. and Withy, R.K. (1992). Orchard and vineyard plant protection guide for inland New South Wales 1992-93 season. NSW Agriculture. 22-23.

Thwaite, W.G., Gordon, R., Penrose, L.J. and Withy, R.K. (1994). 1994/95 Orchard plant protection guide for inland New South Wales. NSW Agriculture. 30-31.

Veitch, R. (1934). Queensland fruit fly control. *Queensland Agricultural Journal* **42**: 672-673.

Vickers, R.A. (1999). Field evaluation of a novel fruit fly bait. Final report, HRDC Project CT98020. Horticultural Research and Development Corporation. 13pp.

Weldon, W.W. (2005). Dispersal and mating behaviour of Queensland fruit fly, *Bactrocera tryoni* (Froggatt) (Diptera: Tephritidae): Implications for population establishment and control. PhD Thesis, University of Sydney. 166pp.

Yeates, D.K., Yeoh, P.B. and Rechichi, S.N. (1992). Trap monitoring for Qfly. In: Sproule, A.N., Broughton, S. and Monzu, N. (Eds.) *Queensland Fruit Fly Eradication Campaign*. Department of Agriculture Western Australia. 92-113.