Crop Protection 76 (2015) 24–32

Contents lists available at ScienceDirect

Crop Protection

journal homepage: www.elsevier.com/locate/cropro

Roving and stationary release of adult sterile Queensland fruit fly, *Bactrocera tryoni* (Froggatt) (Diptera; Tephritidae)

O.L. Reynolds [a, *], B.A. Orchard [b]

[a] Graham Centre for Agricultural Innovation (NSW Department of Primary Industries and Charles Sturt University), Private Mail Bag, Wagga Wagga, NSW 2350, Australia
[b] NSW Department of Primary Industries, Private Mail Bag, Wagga Wagga, NSW 2350, Australia

ARTICLE INFO

Article history:
Received 31 March 2015
Received in revised form
5 June 2015
Accepted 7 June 2015
Available online 20 June 2015

Keywords:
Cue-lure
Sterile insect technique
SIT
Trap recapture
Chilled adult
Sterile release

ABSTRACT

Sterile Insect Technique (SIT) is an environmentally-benign, species-specific method of pest control. The Queensland fruit fly, *Bactrocera tryoni* (Froggatt) (Diptera: Tephritidae) is a polyphagous pest that may be managed via SIT. Sterile releases of *B. tryoni* were carried out in two separate field trials to compare the effectiveness of non-chilled adult (stationary release) and chilled adult (roving release) releases under field conditions in eastern Australia. The first study compared the recapture rates of sexually mature sterile male *B. tryoni* in cue-lure baited Lynfield traps when released as chilled adults and non-chilled adults, each on two release dates in an urban town. In a subsequent field study, trap capture rates of wild and sterile flies were monitored in three isolated towns in New South Wales that received either sterile non-chilled adult releases (Uranquinty), sterile chilled adult releases (Lockhart) or no sterile releases, i.e. control (Cootamundra). Wild fly larval counts (from whole picked fruit) were also obtained in both Uranquinty and Lockhart. In trial 1, for both release 1 and 2 respectively, a greater proportion of non-chilled flies (52.6% and 62.0%) than chilled flies (47.4% and 38.0%) were recaptured per trap. However, over the duration of the trial, recapture of chilled adult flies and non-chilled adult flies was 4.35 ± 0.54% and 3.27 ± 0.54% of all flies released, respectively. Overall, in both releases, adult flies designated for chilled adult release had lower recorded adult eclosion (except for release 2 when more chilled adults emerged) and flight compared with non-chilled adults. In trial 2, Lockhart (chilled adult release) wild fly numbers showed a significant decline four weeks after sterile release, despite both Uranquinty and Cootamundra displaying increases in wild fly numbers at this time. Chilled adults were significantly less likely to take flight than unchilled flies, but of those that dispersed, a greater proportion of the chilled flies were recaptured. Over the entire fruit collection period, there was a significant decline in the number of live larvae and the live larvae per fruit in Uranquinty and for seven consecutive weeks in Lockhart, which was also reflected in the total number of larvae and the total rate per fruit. The results are encouraging, particularly the use of chilled adult sterile release for the control of wild *B. tryoni* populations, and would provide a valuable tool for wild fly management.

1. Introduction

The sterile insect technique (SIT) is an environmentally-benign, target specific option to suppress, contain, prevent or eradicate insect pest populations (Malavasi et al., 2007). The purpose of SIT is to use mass-reared insects, irradiated to render them sterile, to flood the wild male fruit fly population with released sterile male flies thereby minimising the possibility of wild males and wild females mating to produce viable eggs (Gurr and Kvedaras, 2010; Nagel and Peveling, 2005).

The Queensland fruit fly, *Bactrocera tryoni* (Froggatt) (Diptera: Tephritidae), is Australia's most significant biosecurity pest of horticulture. Originally, endemic to the tropical rainforests of north-eastern Australia (Gilchrist et al., 2006), its successful spread to cultivated fruit and vegetables (Lewontin and Birch, 1966) saw a subsequent rise to pest status. The polyphagous nature of this pest,

* Corresponding author. Permanent address: Graham Centre for Agricultural Innovation (NSW Department of Primary Industries and Charles Sturt University), Private Bag 4008, Narellan, NSW 2567, Australia.
E-mail address: olivia.reynolds@dpi.nsw.gov.au (O.L. Reynolds).

http://dx.doi.org/10.1016/j.cropro.2015.06.003
0261-2194/

climatic suitability and the expansion of its cultivated host range have, among other factors, enabled its spread throughout eastern Australia. *Bactrocera tryoni* has been recorded on over 240 plant species from 49 families (Hancock et al., 2000). This pest is managed using a range of techniques including surveillance (trapping), public education, bait spraying, male annihilation technique (MAT), cover sprays and SIT (Dominiak et al., 2003; Meats et al., 2003). Until recently, except in pest free regions and states, cover sprays have dominated most control programs. With the recent restrictions placed on the two key chemicals used in fruit fly control, dimethoate (APVMA, 2015a) and fenthion (APVMA, 2015b), by the relevant government authority, the Australian Pesticides and Veterinary Medicines Authority, endemic and outbreak areas are seeking alternate management techniques. SIT is one such technique.

There are two forms of sterile adult release commonly employed: 'chilled adult' release and non-chilled or 'adult' release. Chilled adult release involves the rapid chilling of sterile flies usually at 3–5 °C for less than 1 h (Enkerlin, 2007; Hernández et al., 2010; Reynolds and Orchard, 2010), but they may be held for another approximately 2 h at this temperature before release (Shelly et al., 2013). This enables the immobilisation and transportation of greater numbers of flies using more compact packaging, permitting reductions in the space required for transportation (Mangan, 1996). Chilled adults are usually released from a moving vehicle (roving release), which permits large volumes of sterile flies to quickly disperse (Meats and Smallridge, 2007). Chilled adult fruit fly release is often used world-wide as part of aerial release programs (Cunningham et al., 1980; Nakamori and Kuba, 1990; Sivinski et al., 2000; Vargas et al., 1995) and unlike adult release it is not commonly used in ground release programs (Fisher, 1996; Dominiak, 2000). There is limited published information of the effectiveness of the roving release of chilled adults (Salvato et al., 2003), and none for *B. tryoni*. Adult release incorporates the mass-rearing of sterile flies provided with food and water within some form of container, which is then transported to the field and opened allowing the flies to freely disperse (Enkerlin, 2007). Also known as stationary release, this form of release is the most common for the bisexual *B. tryoni* strain, usually comprising plastic adult rearing containers (PARCs) or bins as the preferred release method (Reynolds et al., 2012; Reynolds and Orchard, 2010). Although teneral adults have largely been released to date, studies show that the pre-release provision of yeast hydrolysate 'YH' (protein) may enhance several fly fitness and mating performance characteristics (e.g. Perez-Staples et al., 2008; Collins et al., 2014), and, importantly, persistence and abundance in the field (Reynolds et al., 2014, but see Taylor et al., 2013).

Despite the widespread use of chilled sterile adults, studies looking at the effect of chilling on a number of performance variables for pestiferous fruit flies are limited and sometimes inconsistent both between and within species. Although Salvato et al. (2003) found no difference in the flight performance of chilled (for 2.5 h) and non-chilled Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann), Andress et al. (2012) showed that flight performance of sterile male *C. capitata* decreased with increasing chill durations of 2, 3, 4, 5 and 6 h concluding that minimising chill time promotes flight performance of released sterile flies. In addition, Shelly et al. (2013) reported that chilling reduced flight performance of sterile male *C. capitata* when held at high densities as opposed to low densities. These authors showed a similar trend for mating competitiveness, however, the reduction in mating performance was only temporary, lasting no more than 3 days. Flight performance of sterile male melon fly, *Bactrocera cucurbitae* (Coquillett) was not affected by increasing chill durations of 1, 2.5, 3 and 4.5 h (Tanahara and Kirihara, 1989). The attractiveness of chilled sterile male Mexican fruit flies, *Anastrepha ludens* (Loew) to females did not differ from unchilled sterile males and with recently colonized males (Mangan, 1996). However, in a more recently colonised strain of females, chilled males attracted the most females (Mangan, 1996). Hernández et al. (2010) showed that of three adult fly densities (1, 1.2 and 1.3 fly/cm^2), there were no differences at the lowest density, in the longevity and flight performance of adult *A. ludens* and the West Indian fruit fly, *Anastrepha obliqua* (Macquart) using three different chilled adult emergence and release systems. However, at the higher densities tested, a decrease in these variables was observed. Recent studies have shown that chilling does not adversely affect male *B. tryoni* longevity or propensity for flight (Reynolds and Orchard, 2011). The often large volumes of flies required and immense travel distances between the location of fly production and release make chilled adult release an attractive alternative to adult release for *B. tryoni*.

The main objective of this study was to determine the effectiveness of adult (stationary) and chilled adult releases (roving) of sterile *B. tryoni* under field conditions. Specifically, we compared the recapture rates of sterile male *B. tryoni* when released as chilled adults (roving release) and non-chilled adults (stationary release). In a subsequent field study, we compared wild and sterile fly abundance of sexually mature sterile male *B. tryoni* over the peak fruit fly season (i.e. summer) until late autumn in three towns in the Riverina, New South Wales, a major horticultural production area in Australia, that received either chilled adults, adults or no sterile flies (control). *Bactrocera tryoni* larval counts of infested fruit in the towns that received sterile flies were also compared.

2. Materials and methods

2.1. Study insects

Bactrocera tryoni were obtained as pupae from the Fruit Fly Production Facility (FFPF) at the Elizabeth Macarthur Agricultural Institute, Menangle, New South Wales (NSW), Australia, marked with either of two distinguishable colours, Pink or Arc chrome (Fiesta FEX 1 fluorescent pigments, Swada, 30–32 Kilkenny Court, Dandenong South, Victoria, Australia). Flies were marked with 1 g dye per 100 g pupae, enabling us to distinguish between treatments. Eight-day old pupae were irradiated with 70.3–74.5 Gy of Gamma radiation at the Australian Nuclear Science and Technology Organisation (ANSTO) facility at Lucas Heights, NSW to render them sterile before they were transported by road to Wagga Wagga Agricultural Institute (WWAI) entomology laboratory in NSW. Insects were reared out in a growth room at WWAI at 26 ± 2 °C, 65 ± 15% RH and a light:dark period of 14:10 with a simulated dawn and dusk as the lights ramped up and down at the beginning and end of the photophase until release. Two separate trials were conducted and depending on each consignment, individual pupae weighed on average for trial 1, 11.4 (release 1) and 11.0 (release 2) mg and for trial 2, 9.85–11.38 mg respectively, which is within the expected range produced by the FFPF (Dominiak et al., 2008). When tested in all trials, the majority of sterile flies were aged 2–3 days.

2.2. Emergence and flight

For the Wagga Wagga trial (trial 1), we determined the proportion of adult flies that eclosed successfully and left each PARC (Silverlock MH 0110, colour "natural") for each treatment, defined as the 'rate of fliers'. To do this, we sampled the *B. tryoni* debris from each PARC (comprising empty pupal cases, un-emerged pupae, partly emerged adults, deformed and non-deformed dead fruit flies