REVIEW OF SUPPRESSION PROGRAM USING THREE GROUND RELEASE METHODS OF STERILE QUEENSLAND FRUIT FLY *BACTROCERA TRYONI* (FROGGATT) AT WAGGA WAGGA, NSW, IN 1996/97

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Summary

Sterile Queensland fruit fly (Qfly) *Bactrocera tryoni* (Froggatt) were released at Wagga Wagga to suppress the wild fruit fly population. A total of 82.8 million sterile pupae were delivered to Wagga Wagga, with an overall emergence rate of 66.9% and male recapture rate of 0.016% (0.0246% corrected for emergence) for the nine month release program. Different release methods were selected depending on availability of labour, climate and sterile flies all of which changed considerably during the program. Adult flies were released using cages and bags, and pupal releases used the bed technique. For the entire program, the emergence rates were 87.1% for cages, 89.9% for bags and 63.6% for beds. However the three methods seemed comparable with over 80% emergence when all three methods were used in February. Flies did not tend to leave the cages and bags in the colder months however they more readily left the beds. The optimum densities of the cages were about 800,000 pupae per cage; optimum loading levels for bag and bed release techniques require further research. Wild Qfly were trapped throughout the year including winter, which was contrary to expectations. The CLIMEX model was used to rank the climate at Wagga Wagga for fruit fly survival and the daily survival rate decrement formula was used to compare quality of sterile flies.

INTRODUCTION

The Sterile Insect Technique (SIT) is an important strategy in the control of several species of fruit fly in many countries. Releases of adults are often made by aircraft but this technique is uneconomical in Australia because of the relatively small treatment areas and the low level of sterile fly production. Therefore an efficient ground release system needs to be developed.

Variable results have been achieved from previous ground release programs, including suspended platforms, cages, plastic bins and beds. The ideal technique should ensure good emergence and recapture rates of adult flies combined with a low cost of operation.

The first evaluation of SIT for control of Queensland fruit fly (Qfly) *Bactrocera tryoni* (Froggatt) in Australia (Andrewartha *et al.* 1967) used the platform release technique (Monro and Osborn 1967). Since then, adult fly release using the plastic bin technique has been the most commonly used release technique in Australia. This method was first used in the control program for Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann) at Carnarvon, Western Australia (Fisher *et al.* 1985). Irradiated pupae are placed in the release bin (commonly available 45 L garbage bins) and held for several days at 26°C until most flies emerge. The bins are then usually taken in air-conditioned vehicles to the field and the flies released in a predetermined grid pattern. The adult fly bin release technique has been used in Qfly SIT release programs in Western Australia (Fisher 1992), at Cowra (James 1992), at Griffith (Horwood and Keenan 1994), and at Adelaide (Perepelicia and Bailey 1993, Perepelicia *et al.* 1994; Reynolds *et al.* 1995; Jackman *et al.* 1996; Perepelicia *et al.* 1997). The bin technique was modified for pupal release at Wodonga (MacFarlane and Betlinski 1988).

However the adult fly bin release system has raised some problems where suitable holding facilities are not available near the release sites. For example, increased humidity and temperature along with increasing ammonia from excreta may cause adult fly mortality (James 1992; Horwood and Keenan 1994) even with moderate ventilation. Other characteristics of surviving adults, such as flightability and mating competitiveness, are also likely to decrease.

These problems are less likely to occur in mesh-sided holding cages where normal airflow or ventilation prevents humidity, temperature and ammonia increasing to damaging levels. Field cages are less reliant on suitable holding facilities and give acceptable results once optimal densities are determined (Dominiak *et al.* 1998).

Sivinski *et al.* (1994) describe a mesh bag that was developed for the mass release of adult braconid parasites. They offer greater efficiency of distribution over large areas for released flies compared with the same number of flies released by the cage method. Bags are easy to store, manoeuvrable and use less space than bins but use slightly more space than a cage holding an equivalent number of flies. This release technique has not been previously used in Australia and was proposed for field evaluation.

An artificial bed technique was reported by Theuniissen *et al.* (1975) and adapted by Dominiak and Webster (1998) for Australian conditions. This pupal release method provided acceptable results and was not reliant on holding rooms.

This paper reports on a suppression program in Wagga Wagga city using the cage, bag and bed methods of release with the intention of finding a release method using minimal resources while yielding optimum emergence and recapture rates and suppressing wild fly populations.

METHODS

The CLIMEX model (Yonow and Sutherst 1998) was used to assess the recapture rates in relation to climatic suitability of Wagga Wagga for survival of both wild or sterile Qfly. Weather data (maximum and minimum temperature, rainfall, pan evaporation) were obtained from an automatic meteorological station outside of the city limits. Yonow and Sutherst (1998) found that town irrigation increased the potential range of Qfly and they provided for town irrigation at 25 mm per week in the summer half of the year and 10 mm per week in the winter half of the year. Subsequently, Mavi (pers. com.) advised that irrigation equivalent to 0.7 of pan evaporation was more appropriate as this irrigation regime prevents wilting. The CLIMEX model was run accordingly and values generated on a weekly basis for all indices.

Meats (1998a) reports a method for calculating a measure of the quality of sterile flies at release in relation to their ability to survive (p_{xs}). Meats (1998b) calculated this quality measure for 9 different programs, including the 1995/96 Wagga Wagga suppression program. This measure was calculated for the current Wagga Wagga release data and compared to the past values calculated for other programs.

Pupae were irradiated and air freighted from the TriState Fruit Fly Production Facility at Camden to Wagga Wagga at weekly intervals from September 1996 until the end of May 1997. Detailed descriptions of production and the irradiation process are given by Terras *et al.* (1997). Sterile pupae were marked with fluorescent pink, orange and blue dyes during different parts of the program. Over 82 million pupae were sent to Wagga Wagga during the 38 week release period.

On arrival at Wagga Wagga, the pupae were either transferred to the same field cages as described by Dominiak *et al.* (1998) or bags, similar to Sivinski *et al.* (1994) in the holding facilities, or transported in an air conditioned vehicle to the bed sites and established as described by Dominiak and Webster (1998). The bags were made from nylon mesh screen with velcro seams on three sides; bags were hung from a wire frame and the ten bags were hung from a metal frame, similar to a dry cleaner's rack.

Densities of pupae and flies in the cages, bags and beds depended on the total number of flies received from the production facility. The cage densities in this study varied from 120,000 to 830,000 per cage, depending mainly on the total number of pupae supplied. Densities inside the bags varied from 20,000 to 80,000 pupae per bag (Figure 1). Most flies emerged in the cages and bags within three days of receipt. These flies were then transported to the release points in Wagga Wagga city and liberated, usually in the shade of a tree, fruiting or otherwise. Release sites were selected weekly based on trap catches from the previous week; releases were made at sites of high wild populations and often changed weekly.

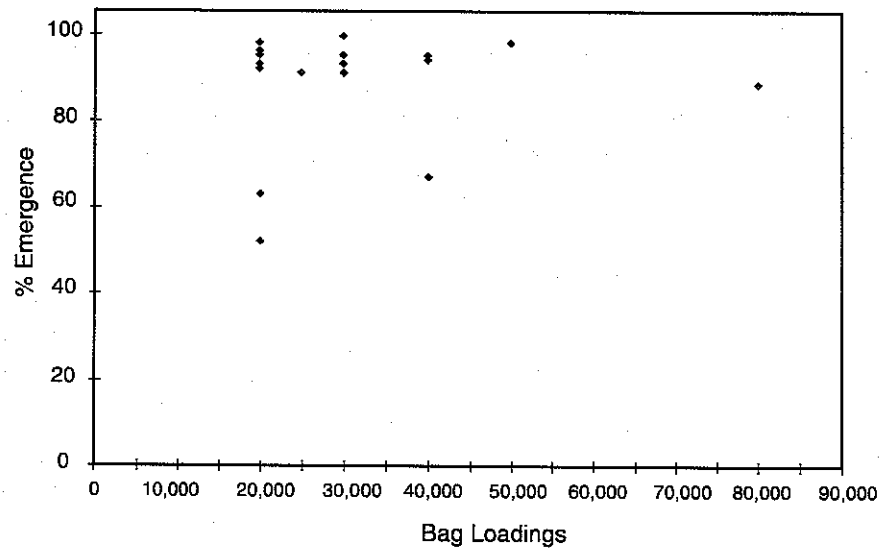

Figure 1. Emergence rates of the bag technique at different bag densities.

The beds were made of double washed river sand with a bottom layer being about 1 cm deep spread over level soil or short grass. A layer of pupae was poured over the base sand layer and covered with another layer of sand about 1 cm deep. Beds were circular and never larger than one metre in diameter with sites ranging from 80,000 to 400,000 pupae per bed.

On many occasions, two different types of release techniques were performed at the same time (Table 1) depending on pupal supplies, field conditions and available staff. One hundred pupae were sampled from each batch received for release to assess batch emergence. These pupae were allowed to emerge separately in an uncovered Petrie dish in the holding facility as a control. To assess emergence from different release techniques, samples of about 1,000 pupae were taken from the pupal layer in the cages, bags and beds at the end of one week since bags and cages had to be emptied and cleaned in preparation for reuse each Wednesday. Counts were made of empty puparia, partly emerged adults and unemerged pupae after emergence to determine emergence rate; empty puparia were assumed to equal emergence rate.

Wagga Wagga is the largest inland city in New South Wales with a population of 55,000 and covering about 28 square kilometres. In the city, there were 58 male Qfly traps (Lynfield) deployed on about a 400 m grid to monitor populations of wild and sterile Qfly populations. These traps are checked weekly from November to May, and fortnightly in the rest of the year. All trapped flies were examined under a binocular microscope, with a blue filter in the light source, for glowing traces of the fluorescent dye marker. Any flies without obvious dye adhering to wing and coxal cavities or in the ptilinum were classed as wild flies. Detailed dissection of the ptilinum or the testes was not undertaken due to lack of resources.

The sterile:wild ratio of captured flies was calculated for each month. A broad estimate of monthly recapture rate was also calculated by dividing the monthly number of sterile flies recaptured in any given month by the number released in the previous month. Dominiak and Webster (1998) reported that the majority of sterile flies were recaptured within one month after release. This method is comparatively quick and allows an evaluation of activity within the year, rather than just examining the annual figure alone.

Emergence rates from pupal layer (cages, bags, and beds) were transformed using the arcsin transformation and compared using one-way ANOVAR. Correlation analysis was used to compare bed emergence with mean weekly temperatures, average weekly maximum temperatures, average weekly minimum temperatures and mean weekly relative humidity. Wild male capture numbers were also compared with weekly temperatures and relative humidity variables using correlation analysis.

Table 1. Monthly summary of total number of pupae delivered to Wagga Wagga and the release strategies used.

Month	Weekly number of pupae delivered ($\times 10^6$)	Type of release
September 1996	2.054	cage
October 1996	2.055	cage, bag and bed
November 1996	0.830	cage and bag
December 1996	*0.460	cage and bag
January 1997	0.834	cage and bag
February 1997	0.930	cage and bed
March 1997	0.915	cage and bed
April 1997	2.716	cage and bed
May 1997	8.600	bed
Total	82.811	

* This is based on only three deliveries in the five weeks of December. The average delivery for the three operational weeks of December was 767,000.

RESULTS

In this suppression program, more than 82 million sterile pupae were received for release (Table 1). When corrected for weekly emergence, a calculated total of about 55 million adult flies emerged (66.9%) during the entire program and assuming 1:1 male:female ratio, approximately 28 million sterile males were released (Table 2). There was a 0.016% male recapture rate based on pupae deployed and a recapture of 0.025% of adults emerged from the pupal layer. A comparison of the emergence results of this study and other Australian sterile Qfly release programs is given in Table 3.

The daily survival rate decrement (Meats 1998a) was calculated to estimate the quality of sterile flies. For the data from this suppression program, using the appropriate equations from Meats (1998a and 1998b), a range 58–72 % was calculated for the daily survival rate decrement. These values are compared to the daily survival decrement of other programs (Table 4).

Normally, Wagga Wagga has a winter rainfall pattern and Qflies would be unlikely to survive in an unmodified environment in dry summer. By running CLIMEX with an town irrigation equivalent to 0.7 of pan evaporation to prevent wilting, the Moisture Index (MI) is not limiting (Figure 2) and the Temperature Index (TI) governs the Growth Index (GI) of Qfly populations. Day Degrees (DD) accumulated are also calculated.

Table 2. Monthly estimates of sterile males released and the numbers of sterile and wild male Qflies caught in monitoring traps. The monthly sterile:wild ratio, estimated monthly sterile fly recapture rate and CLIMEX DD (Day Degrees), GI (Growth Index), TI (Temperature Index) and CS (Cold Stress) are also provided. Release methods used in each particular month is in Table 1.

Month	Estimated numbers of male Qflies released ($\times 10^6$)	Numbers of sterile flies caught	Numbers of wild flies caught	Average number of wild flies per trap per week	Sterile :wild ratio	Estimated monthly sterile fly recapture rate (%)	Average weekly CLIMEX indices		
							DD	GI and TI	CS
Aug 1996	nil	0	20	0.09			4.3	4.8	391
Sept 1996	3.578	1	37	0.16	0.02	<0.001	13.0	13.8	196
Oct 1996	4.477	227	107	0.37	2.12	0.006	28.0	30.8	0
Nov 1996	1.601	1,519	11	0.05	138.09	0.034	38.0	41.8	0
Dec 1996	0.431	746	643	2.77	1.16	0.047	60.0	66.0	0
Jan 1997	1.828	591	675	2.91	0.88	0.137	85.6	91.2	0
Feb 1997	1.450	1,566	2,866	12.35	0.55	0.087	93.0	73.5	0
March 1997	1.532	760	1,364	5.88	0.56	0.052	51.0	56.3	0
April 1997	4.270	495	552	2.38	0.90	0.032	31.0	34.0	0
May 1997	8.686	273	603	2.60	0.45	0.006	13.3	14.5	168
June 1997	nil	24	68	0.20	0.35	<0.001	3.5	3.8	412
July 1997	nil	1	23	0.10	0.43		1.6	2.0	459
August 1997	nil	0	22	0.09	<0.01		3.5	4.3	408
Total	27.704	6,807	6,961	(average) 2.30					

Table 3. Emergence rates of irradiated Queensland fruit fly from Australian programs, including release methods and densities, compared with this study.

Location	Emergence average (%)	Range (%)	Release Method	Densities per release method	Study/Location
Manilla, NSW		43–68	Platform	not reported	Andrewartha *et al.* 1967
Warren, NSW		42–81	Platform	not reported	Andrewartha *et al.* 1967
Warren and Trangie, NSW		14–90	Platform	not reported	Andrewartha *et al.* 1967
	70	61–82	Bin	not reported	MacFarlane and Betlinski 1988
Perth, WA	60.7		Bin	about 25,000	Fisher 1992
Cowra, NSW (Oct-Dec)	53		Bin	up to 40,000	James 1992[1]
Cowra, NSW (Feb-Apr)	31.4		Bin	up to 40,000	James 1992[1]
Cowra, NSW (Apr-May)	72.7		Bin	up to 40,000	James 1992
Adelaide, SA	62	47–80	bin	15,000	Perepelicia and Bailey 1993
Griffith, NSW		54–61	bin	about 20,000	Horwood and Keenan 1994
Adelaide, SA	70		bin	15,000	Perepelicia *et al.* 1994
Adelaide, SA	60	46–73	bin	15,000	Reynolds *et al.* 1995
Glenside—Adelaide, SA	67.8		bin	15,000	Jackman *et al.* 1996[2]
Moana—Adelaide, SA	68.4		bin	15,000	Jackman *et al.* 1996[2]
Glenside—Adelaide, SA	86.3		bin	15,000	Jackman *et al.* 1996[3]
Moana—Adelaide, SA	89.05		bin	15,000	Jackman *et al.* 1996[3]
Adelaide, SA	79.2	58–100	bin	15,000	Perepelicia *et al.* (1997)
Wagga Wagga, NSW	74.7	68–84	cage	0–500,000	Dominiak *et al.* (1998)
Wagga Wagga, NSW	68.2	32–84	cage	500,000 –750,000	Dominiak *et al.* (1998)
Wagga Wagga, NSW	68.1	20–83	cage	750,000 –999,999	Dominiak *et al.* (1998)
Wagga Wagga, NSW	39.8	13–65	cage	> 999,999	Dominiak *et al.* (1998)
Wagga Wagga, NSW	86.6		cage	0–600,000	this study
Wagga Wagga, NSW	88.0		cage	600,000 – 830,000	this study
Young, NSW	82.3		bed	800 000	Dominiak and Webster (1998)
Wagga Wagga, NSW	63.4	22–92	bed	80,000 – 400,000	this study
Wagga Wagga, NSW	89.0	52–99	bag	20,000–50,000	this study

[1] This study suffered mortality due to transport problems.

[2] These flies were reared at the Gosford Horticulture Research and Advisory Station.

[3] These flies were reared at Biological and Chemical Research Institute, Rydalmere.

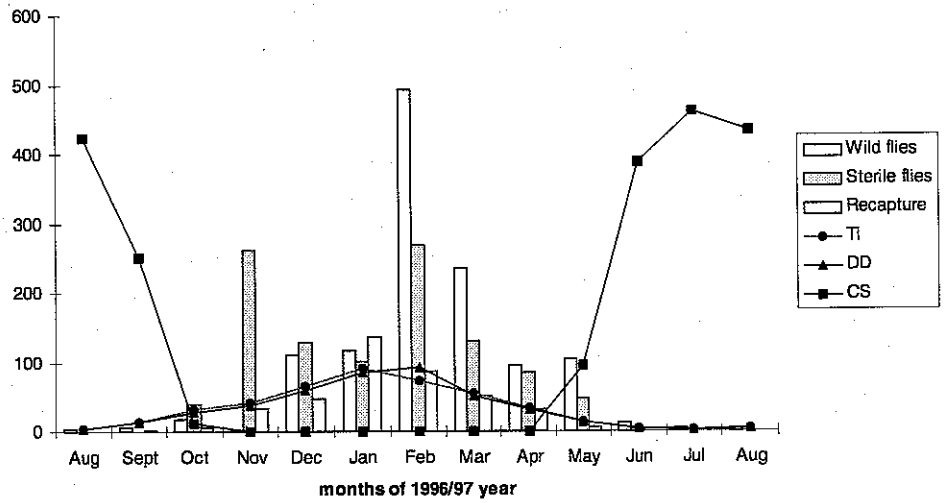

Figure 2: Monthly number of wild and sterile flies caught per ten traps, monthly sterile recapture rate, and average weekly Temperature Index (TI), average weekly Day Degrees accumulated (DD) and Cold Stress (CS) from CLIMEX for Wagga Wagga between August 1996 and August 1997.

Table 4: Quality assurance measures for SIT flies using the Meats daily survival decrement.

Release Campaign	Daily survival decrement (100 p_{xs}) (% of wild)	Reference
Wangaratta	93[1]	MacFarlane *et al.* (1987)
Tharbogang (b)	89–92[1]	Horwood and Keenan (1994)
Tharbogang (a)	83–88[1]	Horwood and Keenan (1994)
Perth	79–86[1]	Sproule *et al.* (1992)
Adelaide (c)	65–77[1]	Jackman *et al.* (1996)
Wagga Wagga 95/96	65–77[1]	Dominiak *et al.* (1998)
Cowra	59–72[1]	James (1992)
Wagga Wagga 96/97	58–72	this study
Adelaide (b)	50–66[1]	Perepelicia *et al.* (1994)
Adelaide (a)	43–61[1]	Perepelicia and Bailey (1993)

[1] Values from Table 1 in Meats (1998a)

During the study period, the meteorological data, without the addition of town irrigation, result in a cumulative GI of only 347 with a MI of 0 for 13 weeks due to the usual summer deficient rainfall pattern. In the modified or urban environment, CLIMEX predicts a cumulative (GI) of 2228 with a MI of 100 for all weeks of the year, including the normally dry summer. CLIMEX calculated that 1831 degree days accumulated over the 1996/97 year equating to 4.8 generations for the year. The two weeks with the highest degree days accumulated occurred in February coincident with the highest monthly trappings of wild and sterile flies. The TI and GI peaked in January.

According to Yonow and Sutherst (1998), GI values between 0–0.99 indicate the environment as unsuitable for fruit fly establishment, 1 to 10 as marginal, 10.1 to 20 as suitable, 20.1 to 40 as very suitable and 40+ as optimal for fruit fly. Temperature conditions at Wagga Wagga were optimal for 5 months and very suitable also for 3 months (Table 2). The four remaining months had a CS of over 100, a reported lethal cold stress, but two of these months had a TI rated as suitable.

The recapture numbers for sterile males and capture numbers of wild males are given in Table 2 along with the calculated sterile:wild ratio and the calculated monthly recapture rate. Numbers of wild

males caught in the traps were directly correlated with both minimum and maximum temperatures in the field (n = 32, calculated correlation coefficient r = 0.690 and 0.601 respectively). Figure 2 shows wild male capture numbers graphed against sterile recaptures and TI, DD, and CS from CLIMEX. The monthly capture rate of wild and sterile flies, and the monthly recapture rate is provided as flies per ten traps per month

Wild flies were trapped in all months (Table 2) of the study period including the coldest month (by all CLIMEX indices), July 1997, with a TI of 2, DD of 1.6 and a CS of 459, a supposed lethal stress. The average monthly maximum temperature was 13.5°C (range 8.9°C to 17.7°C) and an average monthly minimum temperature of 3.2°C (range -5.1°C to 9.4°C).

Wild flies were trapped in low numbers during August and September 1996 with a spring peak in October, which we considered to be the flights of overwintering adults as warmer temperatures occurred. This was followed by few trapped wild flies in November followed by the summer peak. The parameters for October's spring peak were an average monthly maximum temperature of 22.4°C (range 14.5°C to 30.7°C), average monthly minimum temperature 8.6°C (range 3.2°C to 14.3°C), an average of 28 day degrees accumulated weekly and an average weekly TI of 30.8 and CS of 0. All these values increased in November indicating the climate did not cause the decreased trappings in November.

The October flight would appear to be the first opportunity, allowed by climate, for Qflies to fly to mating sites after winter. The CLIMEX model requires the accumulation of 380 day degrees for one generation and, after the October peak, this accumulated in mid December. However there was no pronounced peak of wild flies at this time suggesting the October sterile fly populations suppressed this expected peak of wild flies. Sterile releases and trappings declined in December and the third predicted peak in wild numbers (after 380 DD) near the end of January is likely to be largely not suppressed.

Based on observations from several releases in more isolated suburbs, it was concluded that sterile males released from cages travelled up 400 metres from release sites. This would appear to agree with the release strategy used by Perepelicia *et al.* (1993), Perepelicia *et al.* (1994), Reynolds *et al.* (1995) and Perepelicia *et al.* (1997).

The last cage released fly was recaptured on 11/4/97, but cage releases continued till 23/4/97. It therefore appeared that cage releases were not suited to releases in April.

The CLIMEX TI averaged 34 for April with an average monthly maximum temperature of 24.2°C (range 17.7°C to 29.3°C) and an average monthly minimum temperature of 8.0°C (range 0.4°C to 12.5°C). A fly released by bed technique was found 500 metres from the release site. The last bed release occurred on 28/5/97 and the last bed released fly was recaptured on 10/6/97 indicating that it survived at least 12 days in early winter. The CLIMEX TI in June was 3.8 when the average monthly maximum temperature of 14.8°C (range 10°C to 20.3°C) and the average monthly minimum of 3.9°C (range -2.9°C to 11.8°C). The Cold Stress (CS) in May and June was 168 and 412 respectively; Qfly should not survive when any CLIMEX stress exceeds 100. The last sterile fly was recaptured on 8/7/97 but the colour was not recorded; this trapping was coincidental with trapping about 30 wild flies over a two week period in July 1997; the climatic conditions are described above.

Previous results (Dominiak *et al.* 1998) showed the optimal density for this cage design was between 600,000 to 800,000 pupae per cage. Emergence in this study from the cages containing 600,000 or less pupae averaged at 85.6% (SE = 5.7, n = 14). Emergence from all cages including ones up to 830,000 pupae per cage was 87.1 % (SE = 4.4, n = 18).

Emergence rates from the bags ranged between 52–99.5%, average 89.9% (SE = 2.9, n = 21) using densities from 20,000 to 80,000 pupae per cage (Figure 2).

Emergence from the beds varied between 22–94%, averaging 63.8% (SE = 3.6, n = 23). Rate of emergence from these beds was weakly correlated with average weekly maximum and minimum temperature (n = 11, calculated correlation coefficient r = 0.712 and 0.647 respectively), but not relative humidity (n = 11, calculated correlation coefficient r = -0.401). The average emergence from beds in February, March, April and May was 81.3%, 75.4%, 54.0% and 50.5% respectively with an estimated daily average temperature of 26.9°C, 19.3°C, 15.6°C, and 13.1°C for those months.

The emergence from the control (petrie dish) samples was compared with the emergence from the cages, bags and beds. Control emergence of adults differed significantly from emergence in both the cages ($F = 24.7$, $df = 35$, $p<0.05$, $n = 18$) and the bags ($F = 74.7$, $df = 39$, $p<0.05$, $n = 20$). There was no difference between the emergence from the control sample inside the holding facility and the pupal layer collected from the beds deployed in the field ($F = 0.32$, $df = 19$, $p>0.5$, $n = 10$).

Of the three dyes, the blue dye was found to be removed from the fly after about three weeks and so its use was discontinued. While the pink and orange

dyes appear to be quite separate colours in the factory prior to application on pupae, they appear very similar under the blue filter in the light source. Differentiation between these two colours proved quite difficult and time consuming; subsequently these colours were amalgamated and some evaluations and comparisons between different techniques could not be finalised as originally planned.

DISCUSSION

The aim of this suppression program, along with two other previous reports (Dominiak *et al.* 1998, Dominiak and Webster 1998) was to explore the success of SIT suppression of wild Qfly populations using minimal resources.

The Meats daily survival rate decrement formula (Table 4) indicates that this year's suppression program was less successful than the previous year. However it should be noted that the 1995/96 program ran for three months in summer; the 1996/97 program operated for nine months including cooler months.

The recovery (recapture) rate of sterile flies is one measure of success. High recovery rates may be a reflection of pupal quality, may be influenced by climate after release of flies, and are likely to be influenced by the density of traps. The recapture rate of 0.0246% in this study compares with the previous year of 0.0677%. The broad estimate of monthly recapture appears to be reasonable as the calculated peak monthly recapture rates were in January and February which generally match the peak activity for wild fruit fly populations. The colder months of October and May understandably had poor monthly recapture rates despite large releases in previous months. If the calculated monthly recapture figure is a reasonable estimate of sterile fly activity and if recapture rate is the only basis for judging sterile release programs, it suggests that there is little value in releasing flies before November or after April.

CLIMEX provides the GI and DD indices which are generally similar in value. GI (and TI) peak in January as did the recapture rate. DD peak in February as did peak trappings of both wild and sterile flies (Table 2). Both wild and sterile flies were trapped in months with a CS>100, a reported lethal stress; this last circumstance appears not to fit the CLIMEX model as expected.

The current perceptions are that an overflooding ratio of 100 sterile males to one wild male needs to be maintained to control a wild population (James 1992; Horwood and Keenan 1994; Meats 1996). This was achieved in October (Table 2). However deliveries, and therefore releases, of sterile pupae diminished in November and were very low in December (Tables 1 and 2) including no deliveries and releases over two weeks at Christmas. It might be concluded from Figure 1 that the sterile flies suppressed the wild flies in November however wild populations recovered in December, resulting in loss of the required overflooding ratio. A similar circumstance of decreased supply and release of sterile flies at a crucial time, and resultant loss of overflooding ratio, was reported by James (1992).

Releases from the cages and bags were done in areas where high numbers of wild flies were caught in the previous week. This technique appears to be of little value when detailed records were examined. It is proposed that many wild flies were caught in traps during their dispersal phase some distance from their emergence point. Releasing sterile flies into these areas one week later never allowed a large population of sterile flies to establish in any particular area. Subsequent trappings often detected many sterile flies and no wild flies. For future programs, it is proposed to return to the established release points which would allow 'cones' of sterile flies to establish at each release site and steadily spread out from these sites (Plant and Cunningham 1991; Baker and Chan 1991; Vargas *et al.* 1995). This fixed release grid was used in most previous programs (MacFarlane and Betlinski 1988; Fisher 1992; James 1992; Horwood and Keenan 1994; Perepelicia and Bailey 1993; Perepelicia *et al.* 1994; Reynolds *et al.* 1995; Jackman *et al.* 1996; Perepelicia *et al.* 1997).

Three methods of release were field tested with emergence rates determined to assess the value of each method. The comparative resource efficiency of some release techniques were described by Dominiak *et al.* (1998), and emergence rates of other release techniques and programs are given in Table 3.

The overall emergence from the cages (87.1%) and bags (89.9%) compare favourably with other release strategies used in Australia (Table 3), and offer alternative SIT release methods to the bin release technique. It appeared the optimal maximum densities for the bags were not reached in this study as emergence remained high despite the highest densities (Figure 2). The comparison between cages and bags is that it would take 10 bags (at 80,000 per bag) to release the same number of flies as one cage (800,000 flies per cage). During field distribution of adult flies, the 10 bags are likely to distribute flies more evenly ('low density, high frequency' in Dominiak *et al.* 1998) over an area compared with the one cage. Dominiak *et al.* (1998) attempted to distribute flies more evenly by moving the release cage several times in a short time however there is no way to control the number of flies leaving the cage at each release site, compared with bags, bins or beds.

Previous results (Dominiak *et al.* 1998) showed the optimal densities for this cage design was between 600,000 to 800,000 pupae (average emergence was 74.7%). Emergence in this study from the cages with 600,000 or less pupae averaged at 85.6%, whereas emergence from cages with up to 830,000 pupae was 87.1%, indicating the optimal density for this study was similar to that found by the previous study. The overall better performance from the same cages and the same facility suggest that staff were more familiar with the technique which contributed to the better outcome.

The cage method became increasingly difficult to operate as local temperatures became colder. Flies were increasingly reluctant to leave the cages, particularly during days when temperatures were less than 17°C in April. The longer the cages were left in the field, the more they became prone to predation and vandalism.

The bed technique, with an overall emergence 63.4%, appears to be less successful than cages and bags. However the bed emergence of 81.3% in February compared to the average of 87.1% for cages and 89.9% for bags is encouraging, given the considerable labour savings in the bed technique. The emergence rate from beds was about 50% in April and May suggesting the release technique works at low temperatures and may be improved.

The 12 day survival of a bed released fly in winter may be a reflection of some acclimatisation of pupae before emergence (Meats and Fay 1977, Fay and Meats 1987). Flies reared in ideal conditions in bags or cages have no chance to acclimatise to local conditions prior to release and this may be reflected in the low recapture rate of cage released flies in April. However the longer survival of bed released flies may also be a reflection of the large numbers released by the bed technique rather than any acclimatisation. The possible acclimatisation benefit by the bed technique requires further research.

The emergence from the Petrie dish control pupae differed significantly from the pupal layer counts for both the cage and bag release but not the bed release technique. The differences in emergence rates between the cages or bags and the 100 pupae sample were never consistent, i.e. one was never consistently higher or lower than the other. The uncovered Petrie dish in the same coolrooms was not a good indicator of the actual emergence rates from the cages and bags. There appeared to be no value to maintain this practice in future programs. Perepelicia *et al.* (1994) also reported a difference between the open Petri dish emergence (68%) and emergence (81%) in bins in their rearing facility.

The emergence rates of the control pupae in the coolroom did not differ from the bed emergence in the outside environment. The pupae in the beds were subjected to changing weather while environmental conditions were controlled in coolrooms. We have no explanation for this result.

We conclude that a successful suppression program cannot afford to suffer reduced supplies of sterile fruit fly in the early stages of the program. The use of CLIMEX and the Meats daily decrement formula allow comparisons with other programs while making allowance for variations in climate in different years. The wild Qfly at Wagga Wagga were caught in traps in winter, contrary to expectations. Adult emergence of the bed technique in February is similar to cages and bags which use more resources. In colder months, the pupal bed technique appears to be a better release technique than adult release technique.

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