THE STERILE INSECT TECHNIQUE (S.I.T.)

FOR MANAGEMENT OF
MEDITERRANEAN FRUIT FLIES
IN FRUIT PRODUCTION

~

A TECHNICAL MANUAL
on the preparation for, and initiation of,
S.I.T. for integrated management of Medfly

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- Recommendations on fruit fly population management, fruit sampling, and releasing sterile males are taken from an IAEA Expert Mission Report IAEA-TCR-01550 by Dr Gerardo Ortiz-Moreno (USDA Fruit Fly Exclusion Programme, Mexico) "Sterile insect technique integrated management of fruit fly (Phase II): Report on field operations review of the Medfly SIT control program at the Hex River Valley and buffer zones", 21 October – 8 November 2002.

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1. BACKGROUND

**Growth in the SA fruit industry**

The future growth and profitability of South Africa's fruit industry will to a great extent depend on the successful export of fresh fruit and products to which value can be added.

Successful exports will in turn depend on a number of factors such as production capacity, product quality, logistics and marketing, but also on the availability of an array of environmentally compatible pest management products and techniques which will enable the production of high quality fruit with minimal or zero pesticide residues.

The Sterile Insect Technique (SIT) is one of the major cornerstones on which such a programme can be built.

This Manual concentrates on the use of SIT to suppress Mediterranean fruit fly (Medfly) to levels at which benefits for the international trade in export fruit will be realised. However, codling moth and false codling moth are also the subjects of SIT projects, and Natal fruit fly may later also join the list.

**The need for fruit fly-free or low prevalence areas**

Fruit flies are international quarantine pests – their presence in a country can hinder the free trade in export fruit. This is already happening in South Africa – South Africa cannot export deciduous fruit to certain countries because fruit flies occur in our production areas.

The phytosanitary status of fruit flies is increasing worldwide. A shipment of Spanish citrus was rejected in the USA in 2000 due to the presence of live Mediterranean fruit fly in the fruit. An entire shipment of South African citrus to Spain was turned back in 2003 as a result of the discovery of a single, live Natal fruit fly larva. It is thus expected to become increasingly difficult to access the European market because of the presence of fruit flies in South Africa. Production areas that are either declared fruit fly-free or qualify as an area of low fruit fly prevalence, should be able to retain traditional markets and have easier access to sensitive markets.

An embargo on our fruit due to the presence of fruit flies will have a significant impact on the South African export fruit industry and related industries, as well as on any emerging export fruit growers.

In addition, many international supermarkets increasingly require evidence that the fruit they import is grown under environmentally responsible conditions, which includes minimizing pesticide usage. SIT contributes towards meeting these requirements.

However, there are also other benefits from being able to export from a fruit fly-free or low prevalence areas, including the ability to ship at optimum temperatures for the fruit, and and reducing dependence on methyl bromide fumigation.
Under certain circumstances even individual production areas may be able to achieve fruit fly-free or low prevalence status.

**The concept of SIT**

SIT is nothing more than birth control for insects. For suitable pest insects, large numbers are reared, and the males sterilized and released every week in the target areas. They mate with the wild females which results in infertile eggs being laid, and the wild population then declines rapidly.

- It is a proven technique, used in various other countries including the USA, Argentina, Chile, Australia to create fruit fly-free or low prevalence areas, and can be very cost-effective.

- It is an area-wide technique – it must be applied over large areas, e.g. at least 500 ha depending on certain circumstances. However, the larger the area, the more effective the results will be.

- SIT is highly environmentally friendly, making it very acceptable to export markets, which increasingly focus on eco-logically compatible production techniques.

- Depending on the size of the area under SIT and other factors, there are various options for release of sterile fruit flies, which can have a favourable impact on the cost-effectiveness of SIT.

- SIT is resource and management intensive – it requires a sound funding base, centralised management, very good coordination, and the full cooperation of and compliance by all the growers in an SIT area.

**How can SIT help fruit growers?**

Experience in other countries has shown that three objectives are possible with SIT, with increasing cost implications but with increasing benefits:

- Fruit fly control or suppression in a cost-effective, environmentally compatible manner.

- Creation of an area of low fruit fly prevalence. Fruit flies are present, but at extremely low levels (e.g. an average of 0.001 to 0.0001 flies/trap/day), which may be acceptable to many discriminatory countries.

- Creation of a fruit fly-free area (=eradication; 0 flies/trap/day over at least 12 months), with a fruit fly-free certificate. This will entail establishing quarantine zones to prevent fertile fruit flies being brought into the area by human movement, and is an operation managed and financed by government. There is increasing international awareness that it is very difficult and costly to achieve and maintain a fruit fly-free area.

**SIT Africa (Pty) Ltd and technical expertise**

The production and distribution of sterile Medflies to participating areas, and the oversight of all field operations and public relations, is managed by SIT Africa through a Medfly Facility Production Manager and a Field Operations Manager.

Technical expertise in SIT, area-wide pest management and GPS/GIS is contracted in by SIT Africa from ARC Infruitec-Nietvoorbij and DFPT Research in Stellenbosch.

**Implementing SIT**

The recommendations in this Manual are designed to help SIT personnel and
growers prepare for and initiate a fruit fly suppression programme using SIT. They are based on experience gained by ARC Infruitec-Nietvoorbij and SIT Africa (Pty) Ltd with the SIT programmes in the Hex River Valley, EGVV and Riebeek Valley, and on input from a number of international fruit fly and SIT experts.

Since 1996 the International Atomic Energy Agency (IAEA) in Vienna has played a major role in the establishment of SIT in South Africa by providing significant funding for technology transfer and specialised equipment.

At the time of writing SIT is being used in South Africa for fruit fly suppression in the above three productions areas. When more areas have joined the SIT programme, and there are larger contiguous areas of sterile fruit fly releases, progress towards the creation of low fruit fly prevalence areas, or fruit fly-free areas, can be considered.

Especially the latter will involve some major changes to the programme (e.g. quarantine measures), which in turn will impact on socio-economic issues.

The text in this Manual is divided into recommendations and actions to be carried out i) before the start of sterile fly releases, and ii) at the onset of releases. In some cases pre-release actions have to be changed at the onset of releases.

Recommended actions are placed in shaded boxes...

... followed by further explanations of actions.

This Manual cannot cover all aspects of SIT. In cases of uncertainty, contact either ARC Infruitec-Nietvoorbij or SIT Africa (Pty) Ltd. Contact details are provided at the end of the Manual.
The preparation phase in an SIT programme is critical. Many activities need to be initiated at least 1 year before any sterile flies are released. Infrastructure needs to be put in place, resources procured, data collected, and above all, the wild fruit fly population has to be radically reduced. **SIT cannot work effectively where there are high wild fruit fly populations.**

2. **INFRASTRUCTURE AND RESOURCE DEVELOPMENT**

**Operations centre**

Set up a single operations centre for each area, fully equipped with the necessary office and communication equipment, from which all actions, pre- and post-sterile fly releases, will be centrally coordinated over the area.

As SIT is an area-wide and management intensive technique, **centralised coordination of the SIT programme in any area will be crucial for success.**

The operations centre will contain aerial maps of the entire release area (see "Maps" below). Here, all activities and regular communication between all role-players will be coordinated: weekly fruit fly trap counts received; fruit fly population graphs produced and displayed; host plant management and baiting and sanitation activities coordinated; public relations activities managed, and later, sterile fruit fly releases coordinated.

When the releases of sterile fruit flies start, **additional space with climate control equipment** will be needed for a laboratory, the storage of sterile flies, quality control tests on sterile flies, and for storing, cutting open and monitoring sampled fruit for fruit fly infestation.

**Maps**

In the operations centre display **maps** of the area (e.g. 1:10 000 aerial maps/photos), including urban areas, with 25-ha referenced grids, in the operations centre (see example in Annexure 1). Digitized GIS maps should also have 25-ha grids.

A "bird's-eye" view of the SIT area is essential, for which aerial photos are ideal. One male-only trap will be installed in each 25-ha block. The precise position of each trap will be determined using GPS and clearly indicated by markers on the maps. The position of troublesome host plants can also be similarly indicated. See Section 6.

The grid should not just cover the area occupied by the commercial hosts (i.e. orchards and vineyards), but should include urban areas and also extend about 500 m into natural vegetation outside commercial plantings, including kloofs, river beds and mountainsides.

These maps should be in addition to digitized maps in a GIS programme, where similar and more information to facilitate precision fruit fly management will be included – see Sections 3 and 6.

**Staffing**

**SIT Area coordinator:** Appoint a full-time SIT Area Coordinator. One full-time **Assistant SIT Coordinator** is advised for larger areas, e.g. 10,000 ha and more.

The SIT coordinator will greatly benefit from having a technical background. The coordinator will need to be computer literate and have good knowledge of spreadsheets. A knowledge of pest
management and databases will be a definite advantage.

This coordinator's task will involve *inter alia*:
- coordination of all fruit fly monitoring and population reduction actions;
- communication with the growers and other stakeholders in the fruit industry;
- communication with community groups and the public;
- liaison with ARC Infruitec-Nietvoorbij, SIT Africa (Pty) Ltd and SIT experts on technical matters;
- coordination of data management;
- (when releases of sterile males start) coordination of releases of sterile flies, supervising the identification of trapped flies, and supervising the collection of fruit samples.

**Fruit fly monitors:** Appoint full-time fruit fly monitors; one monitor for between about 100 to 120 fruit fly traps, depending on terrain.

**Monitors must be observant and reliable,** have good eyesight, and be able to distinguish between different fruit fly species. Incorrect data on fruit fly populations could cause the programme to fail.

In order to properly coordinate an SIT programme, certain actions require that **contractors** be appointed to carry out the work and that it not be left in the hands of growers. Such activities include baiting and host plant management.

**Bait application contractors:** Appoint a bait application contractor to ensure that all commercial fruit and other fruit fly host plants in the target area can be regularly baited according to the prescribed programme (see Sections 8, 9 & 10).

The use of **contract bait applicators** is essential for a successful fruit fly SIT programme. Experience has shown that baiting is not effective when left up to individual growers, even when attempts are made to coordinate baiting activities. (See also Section 8 ii).

**Host plant/sanitation manager:** The appointment of a person to coordinate host plant management and sanitation is highly recommended.

Effective management of fruit fly breeding sites are crucial to an effective fruit fly management programme. See Sections 3 and 8 iii).

**Public relations:** An effective public relations function for the SIT programme must be established to continually keep all stakeholders up to date with all activities and outcomes in all SIT areas.

Effective public relations is crucial to the success of an SIT programme. If this function is not timeously, continuously and correctly managed, inadequate public relations will severely hamper the programme. Participating growers and all other stakeholders need to know the finer details of what is involved in the programme, and what will be expected of them. Other organisations that need to be informed and kept up to date with the programme include other fruit growers and fruit industries, export companies, agro-chemical companies and other fruit industry organisations, the public in general, the media and educational institutions.

The public relations function will be carried out by the Manager: Field Operations of SIT Africa, together with the local SIT Area Coordinator. In time, when more areas are included under SIT, a full-time public relations officer may be necessary.
Identification technicians: One or more fruit fly identification technicians will have to be appointed to identify and count all fruit flies caught in the traps. Once releases of sterile fruit flies have started, wild and sterile fruit flies from all weekly trap catches will also need to be identified and counted.

Once sterile fly releases have started these technicians will also be responsible for determining the mating status of all female wild flies trapped (i.e. whether they have mated or not). This aids in determining the success of the programme, and is essential especially in eradication or low fruit fly prevalence areas. See Section 13.

Equipment and consumables

Besides the necessary climate-control equipment (see under "Operations centre" above), the following should be acquired: monitoring traps and lures (see Sections 4 and 10), fruit fly bait and bait application equipment (see Section 8 ii), a suitable GPS instrument, a stereo microscope, insect dissecting equipment, magnifying glasses (head-mounted and/or hand-held), vials, buckets for fruit-sampling.

After sterile releases begin, the following will also need to be procured: racks for storing bags of sterile flies, and a good ultra-violet light for the identification of dyed sterile fruit flies. These identifications need to be made in a darkened environment (e.g. in a well-shaded or curtained cubicle) to enhance the visibility of the dyed flies. Equipment and raw ingredients to prepare food (e.g. agar) for the emerging sterile flies will also be needed.

The correct identification of sterile and fertile flies is essential – fertile flies will have no fluorescent dye on them while sterile flies will have varying amounts of dye on their body. A relatively strong ultra-violet light is necessary to detect small quantities of dye.

Experience has shown that the quality of the resources can make or break the SIT programme. Do not always opt for the cheapest, or take short cuts. You get what you pay for.
3. HOST PLANT IDENTIFICATION

Identify all non-commercial fruit fly hosts in and around the SIT area. Record their positions by GPS, and enter these positions on the digitized GIS maps. See Section 6.

Maintain a host plant database containing details of all types of fruit fly host plants, both obvious (home garden fruit trees) and less obvious (e.g. wild berries, rose hips), and their locality and fruiting times.

Medfly and Natal fruit fly will infest all deciduous fruits and table grapes, all citrus fruits, and a great many other fruits of trees or shrubs, wild or domestic, but to differing degrees (see Annexure 2).

Most fruit flies breed outside commercial fruit plantings, e.g. in home gardens and neglected host trees and fruiting shrubs. These plants give rise to re-infestation of commercial plantings when the commercial fruit ripens.

Knowledge of the identity and locality of fruit fly hosts in and around SIT areas is therefore essential. A serious effort should be made to identify all wild and less common fruit fly hosts in the area, for example wild tree fruits and wild berries, and the time in the season when their fruits ripen. Inclusion of this data on a GIS programme, together with the fruit fly trap catch data, provides invaluable information for reducing fruit fly infestation (see Section 8).

Besides all types of commercial fruit there are a great many wild and ornamental plants that produce fruit or berries that serve as alternate hosts for fruit flies (see examples in Annexure 2). Female fruit flies will lay eggs in just about any fruit or berry that is fleshy, and some of the host plants are not obvious; for example, even very small fruits such as milkwood berries can support the development of one or two fruit fly larvae, and rose hips are also regularly infested by fruit fly.

If you don’t control host plants, you won’t control fruit flies.
Fruit flies can infest just about any fruit or berry, wild, domestic or commercial. Unless all fruit fly host plants in the SIT area are identified and properly managed, the success of the programme will be significantly compromised.
4. CHOICE OF FRUIT FLY TRAP

**Male traps and lures:** For monitoring fruit fly populations before the release of sterile fruit flies, SIT Africa requires that only "Yellow Delta" traps and lures be used. See Annexure 3.

Standardisation of traps and lures throughout the SIT area is crucial so that fruit fly population data on all farms and in all areas can be directly compared.

The use of other types of trap in an SIT programme is not recommended, as it will then be difficult to compare fruit fly population fluctuations from different areas with any degree of certainty. If in doubt, consult ARC Infruitec-Nietvoorbij or SIT Africa.

**At the start of the sterile fruit fly release programme** Yellow Delta traps will have to be changed to one that also traps females. See Section 10.

Further information on fruit fly traps and trapping is contained in an IAEA publication "Trapping Guidelines for Area-Wide Fruit Fly Programmes", available from ARC Infruitec-Nietvoorbij.

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**Do not be lulled into complacency by low trap catches - fruit fly traps catch less than about 10% of the adult population in an area.**
5. TRAP INSTALLATION AND MAINTENANCE

**Trap density:**
In orchards and vineyards, place Yellow Delta traps at a density of 1 trap per 25-ha block. The current GPS position of the trap in each block must be indicated on maps in the operations centre, and must also be marked on the digitized GIS maps. In towns, trap density should be about 1 trap per 5 to 10 ha, and in natural vegetation around the perimeter of the SIT area, about 1 trap per 50 to 75 ha.

Clearly number each trap using a permanent marker for data recording purposes. Each trap number must remain permanently associated with the same 25-ha quadrant.

Before the start of sterile fly releases 25-ha quadrants are used. This will change after the start of sterile fly releases. See Section 10.

Indicating the different wild fly population levels with different size or colour of dot, e.g. green for zero flies trapped, yellow for 1 to 10 flies/trap/week, red for more than 10 flies/trap/week, is a very useful way of keeping up to date with the changing population densities in different areas of the SIT programme.

**Trap placement:** Install traps in late winter to establish baseline infestation levels. Where possible place traps in ornamental trees with reasonably dense foliage rather than in fruit trees, as male fruit flies prefer more dense shade. Traps should be as high as practical (± 2 m), and inside the canopy of the tree on the south eastern (cooler) side. Remove any foliage that comes into contact with the trap. Ensure that the trap entrance(s) remain unobstructed throughout the year.

**Lures:** Place the lure on the glue in the centre of the trap bottom, and ensure that it is not covered with gum.

**Trap maintenance:** Maintain traps and replace lures strictly according to the manufacturer’s specifications.

Lures and trap bottoms must always be effective, or incorrect decisions will be made. Replace trap bottoms sooner than specified if it is evident that the glue is starting to get depleted, or when it is obvious that its efficacy in trapping fruit flies is decreasing, for example when there is excessive dust or debris in the glue. Replace the whole trap if it becomes misshapen or damaged.

**Trap rotation:** If any trap records zero catches for more than a couple of weeks while other traps nearby are trapping fruit flies, move this trap 100 to 200 m away in the same 25-ha block every 4 to 6 weeks. Record any new trap positions on the GIS system and on the aerial photos in the operations centre.

Trap rotation may be necessary avoid a trap staying in one locality in a 25-ha block with an unusually low fruit fly population, which could give a false impression of the block’s population density.

A limited number of Yellow Delta traps can be installed by growers in addition to the SIT traps. However, after releases of sterile males start, these are likely to be of little value as they are likely to trap mostly sterile males.

Further information on fruit fly traps and trapping is contained in an IAEA publication "Trapping Guidelines for Area-Wide Fruit Fly Programmes", available from ARC Infruitec-Nietvoorbij.

You cannot manage what you cannot measure. Ensure that all fruit fly traps are effective and all population measurements are accurate.

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6. USE OF GPS AND GIS

GPS (geographical positioning system) and GIS (geographical information system) are powerful tools in any pest management programme, enabling a wide diversity of geographically-referenced data which is useful to fruit fly management to be precisely recorded and displayed. The most useful of these data includes trap positions, and the precise locality of fruit fly host plants. GPS and GIS facilitates precision pest management.

**Position of fruit fly traps**

| The geographical coordinates of each trap should be recorded using a GPS instrument and downloaded into a GIS programme. SIT Africa will coordinate this activity. |

Mapping trap placements by GPS enables the latitude and longitude coordinates of each trap to be recorded. This in turn enables the trap-catch data for each trap to be downloaded into a suitable GIS programme, a computerized system which will enable a computer-generated map of the area to be printed regularly, showing inter alia the wild fly population densities in each quadrant.

**Weekly trap data**

When the number of fruit flies (and species) trapped per week are entered into the GIS system (see Section 7), the GIS map generated in this way will enable an "eagle's-eye" view of the entire treatment area and show at a glance where the fruit fly problem areas are (see example in Annexure 1).

This information is indispensable in keeping track with the change in fruit fly status of each trap as the season progresses, making it easier to quickly identify problem areas.

**Location of host plants; other data**

| The geographical coordinates of each host plant or group of host plants should also be recorded by GPS and downloaded into a GIS programme. If the type of GPS instrument allows, record also details such as host plant type and ripening times. |

Knowledge of the identification and locality of fruit fly host plants, and the time their fruit ripens, is essential in a fruit fly management programme. Using a GIS programme the locality of problem plants can be easily identified, facilitating better host plant management. See Sections 8 and 10.

Trap and host plant data will be placed on the DFPT Research website on which other pest management data can be added, creating an excellent GIS platform for the optimum planning and execution of pest management practices.

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The high degree of precision in recording events and localities with GPS and GIS, with the ability to see the whole picture at a glance, leads to precision in decision-making.
7. TRAP INSPECTION, FRUIT FLY IDENTIFICATION, AND DATA RECORDING AND MANAGEMENT

**Trap inspection and fruit fly identification**

Inspect each trap once a week, on the same day of the week where possible. Carefully remove all fruit flies and any other insects or debris, taking away as little glue as possible. Record the number of wild Medflies, and the number and identity of any other species of fruit fly (e.g. Natal fruit fly) separately. Stir the remaining glue with a thin stick to ensure that the trap remains effective.

Training in the identification of different fruit fly species and sex is a specialised task and can be given by SIT Africa or ARC Infruitec-Nietvoorbij (see "Contact details for further information" at the end of this manual).

**Data recording and management**

Enter each week's trap catch data into a proforma SIT Africa spreadsheet. Generate graphs of Medfly trap catches per week for the whole area as well as sub-areas, standardizing the units on the y-axis to the average number of fruit flies per trap per day (FTD). The occurrence of any other fruit fly species should be included separately on the same graph.

SIT coordinators should send the weekly trap catch data as soon as possible to SIT Africa. SIT Africa will collate all the data and regularly provide each SIT area with a GIS map indicating wild fly population densities.

FTD is the international standard for recording fruit fly trap catches, and enables data to be compared irrespective of the trap-reading interval. This data can then be used to generate graphs of weekly trap catches of wild Medflies and other fruit fly species over the whole season for the whole region, or for any individual area within the region. An example is given in Annexure 1.

The generation of weekly information on wild fly population levels in different areas will enable SIT coordinators to readily and timeously identify fruit fly hotspots and therefore to take the necessary remedial action. See Section 8.

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Fruit flies are lazy.

Generally speaking, fewer than 20% of the adults will move more than about 100 metres from where they emerge; fewer than 1% will move more than a kilometre.
8. FRUIT FLY POPULATION REDUCTION PROGRAMME

SIT is never a stand-alone technique and should ALWAYS be integrated with other appropriate methods including baiting, sanitation and host plant management. The use of bait sprays is compatible with an SIT programme, as they will unselectively kill both sterile and wild flies. The ratio of sterile to wild fruit flies, which is all-important in an SIT programme, will therefore not be significantly altered by baiting.

SIT is based on overflooding the wild fruit fly population with sterile males at a ratio of at least 80:1 sterile males:wild males, so that there is a far greater chance of a sterile male + wild female mating than a wild male + wild female mating. As a limited number of sterile males can be released each week, it is therefore imperative to first reduce the wild fruit fly population to low levels (e.g. an average of less than 1 FTD) before starting releases of sterile fruit flies, so that adequate overflooding with sterile males can be achieved. If this is not done there will be too many matings between wild males and wild females and SIT will most likely not be effective.

Sanitation and hygiene, host plant management, and baiting, are critical actions that must be carried out to reduce the wild fly populations before starting to release sterile fruit flies. These actions should be on-going throughout an SIT programme. However, in commercial orchards and vineyards the period from post-harvest to spring is critical to prevent high numbers of wild flies surviving the winter. The success of these actions will to a great extent determine the success of the SIT programme.

The use of a GIS/GIS programme will greatly facilitate the host plant management and baiting programmes through being able to accurately pinpoint the areas and specific plants needing attention (see also Sections 6 and below).

i) Sanitation and hygiene

If orchard/vineyard sanitation is neglected, SIT is unlikely to be a success.

Remove and destroy (e.g. by pulping, or placing in black plastic bags left in the sun), or bury at least 1 m deep, all fruit fly-infested and fallen fruit. In vineyards, the removal of "na-trossies" is highly advisable.

Pay particular attention to home gardens. Where the fruit will not be used it is strongly recommended that it is completely stripped from trees when still immature.

Good orchard/vineyard hygiene is absolutely essential in any fruit fly programme. Fallen fruit often contains fruit fly eggs or larvae (see Annexure 6) which will help sustain infestation in orchards and vineyards. In vineyards, fruit fly larvae can complete their development in "na-trossies" as they dry out and become raisins. Green fruit that is stripped from trees early in the season cannot later serve as fruit fly hosts. Good hygiene is also essential in home gardens.

ii) Host plant management

If fruit fly host plant management is not effective, SIT is unlikely to be a success.

Remove, bait or strip fruit from all identified fruit fly host plants, taking into consideration the fruiting times where this has been determined. Domestic fruit trees from which fruit is never usable due to fruit fly infestation should ideally be cut down. "Na-trossies" in commercial vineyards should be removed and destroyed as far as possible. See "i) Sanitation and hygiene" above, Section 3 and Annexures 2 and 4.
The greatest source of fruit fly populations is from infestation of fruit in gardens, neglected orchards and vineyards, and in alternate hosts in e.g. municipal areas and in the veld. Unless these host plants and their localities are known and properly managed, fruit fly populations will never be reduced adequately. "Na-trossies" in commercial vineyards are also a serious threat to any fruit fly reduction programme on table grapes or in commercial orchards bordering vineyards.

Fruit collected from any of these host plants should be treated as described in iv) Sanitation and hygiene below.

iii) Baiting (including "attract & kill")

*If the baiting programme is not effective and coordinated, SIT is unlikely to be a success.*

Female fruit flies need to feed on protein to mature their eggs; they therefore actively seek out protein sources after they emerge from the soil. Males are also attracted to and feed on protein sources. The application of a bait consisting of a protein attractant and a toxin can therefore effectively reduce populations of fruit flies.

"Attract & kill" bait stations are a very useful and practical means of reducing populations in home gardens and other hotspots. The M3 device, comprising a sponge treated with a protein attractant and insecticide, is recommended.

Between October and end of May hang four to six M3 bait stations per host or shade tree, replacing them every 3 months.

The main objective of a baiting programme should be to kill female fruit flies before they mate, and therefore to limit reproduction of the adult generation. A routine, coordinated and area-wide baiting programme using an effective bait formulation, carried out correctly and efficiently, should reduce wild fruit fly populations to low levels suitable for the initiation of a sterile fly release programme.

The main focus of the baiting programme should be all known fruit fly host plants, cultivated and wild, as well as all good shade trees in which fruit flies will often be found.

Note that sugar, including molasses, does not attract fruit flies, but merely stimulates them to feed once they have found the droplet. However, the addition of a suitable form of sugar (e.g. molasses) to the bait will improve its efficacy by stimulating the fruit flies to take in more bait.

A baiting contractor should be used for all baiting operations in order to achieve the necessary level of success. The contractor should preferably be registered with AVCASA, and have experience in fruit fly baiting using quadbikes, and must have equipment suitable to meet the requirements for application of the correct volume of bait per ha with the suggested droplet size and placement – see “Ground-based bait application equipment” below. Experience has shown that baiting by individual growers is not successful in an area-wide programme.

**Bait recipes**

The bait recipes below are registered for ground-based application on deciduous fruit and table grapes. For aerial application of GF-120 only, see "Aerial application of bait" below.
**Bait recipe #1 (GF-120, based on Spinosad 0.24 g/L):**

GF-120 NF: 1.0 – 1.2 litres, **plus:**

Citrus and deciduous fruit:
- Water: 19 – 29 litres
- Application rate: 20 – 30 litres/ha

Table grapes and other crops:
- Water: 9 – 30 litres
- Application rate: 10 – 30 litres/ha

Home gardens:
- Water: 9 – 10 litres
- Application rate: 2 – 3 litres/garden

**NB:** GF-120 should only be applied with special equipment – see "Ground-based bait application equipment" below.

The same equipment can be used for both GF-120 and protein hydrolysate baits.

GF-120 is a ready-made formulation to which only water need be added. It is increasingly becoming the international product of choice in fruit fly management programmes due to its high efficacy as a fruit fly bait – local evaluations have shown GF-120 to be a very effective and rain-fast bait. It has a very favourable ecological profile – it is classified by the USA’s Environmental Protection Agency as a "reduced risk" pesticide, and has low mammalian toxicity with very limited effects on non-target organisms. It is also registered for organic production, and for aerial application.

**Bait recipe #2 (mercaptthon and protein):**

- Mercaptthon 50% EC: 500 ml
- Protein hydrolysate: 2 litres
- Water: 100 litres
- Application rate: 50 – 75 litres/ha

(= 125 – 187.5 ml mercaptthon a.i./ha)

**Note that mercaptthon has been "red-flagged" internationally, and may not be permissible on export fruit in the foreseeable future.**

**Ground-based bait application**

- Apply routinely in a coordinated manner according to the prescribed programme. Application intervals change during the season, from weekly during the growing season to fortnightly during winter. Consult SIT Africa or ARC Infruitec-Nietvoorbij.

- Apply in scattered coarse droplets of 1 to 4 mm diameter for bearing trees (to minimize fruit spotting), and 4 to 6 mm for non-bearing trees, post-harvest, or non-commercial shrubs and trees. Larger droplets are more attractive to fruit flies, and the active ingredients stay effective for longer than in smaller droplets.

- Aim the bait to the southeast quadrant of the tree, in an upwards direction to place it in the centre of the tree, under the leaves where the flies tend to congregate and mate, and where the bait is protected from rain and UV light.

- Apply in the early morning (so that it is the fruit fly's first meal of the day).

- Under conditions of heavy early morning dew, rather apply the bait later in the day.

By following the above recommendations the bait will be applied in such a manner that it is:

- attractive to fruit flies;
- will remain active for as long as possible;
- is likely to be found by fruit flies soon after their emergence;
- and will attract and kill fruit flies throughout the year.
**Bait application sites**

- Apply to all host plants and trees/shrubs with good leaf coverage that provide good shelter to fruit flies, especially in gardens and backyards, over the entire SIT area; the larger the area treated, the greater the efficacy.

- Apply to commercial plantings according to registered recommendations – consult the bait distributor, SIT Africa or ARC Infruitec-Nietvoorbij.

Adult fruit flies will congregate on host plants and trees/bushes offering good shelter. **Gardens and backyards (in towns and on farms) are the main breeding grounds of fruit flies, and are without doubt the major source of fruit flies in and around commercial orchards.** If fruit fly populations are effectively controlled in these areas, fruit fly levels in commercial plantings will decrease significantly.

Very few, if any, fruit flies will occur in commercial orchards early in the season or when fruit is immature; these areas need not be treated with bait until the fruit becomes attractive to fruit flies, typically from about 8 to 10 weeks before harvest, depending on fruit kind. **Bait sprays should then be only applied if fruit fly levels justify it, and then in compliance with relevant withholding periods.**

**Ground-based bait application equipment**

Only use equipment that will apply the bait in the required-sized droplets. **Mistblowers or other equipment delivering fine droplets should not be used**, unless they can be modified to deliver large droplets under low pressure.

For citrus or trees with dense canopies preferably use equipment that applies a thin, solid stream (e.g. spraying systems D1 – D3 nozzle tips without whirl plates) at a pressure of 2-3 bar, aimed upwards into the centre of the tree canopy. When the thin stream strikes any obstruction at the suggested pressure, it will break up into droplets of the desired size inside the canopy. Use as many nozzles as necessary to meet the required delivery per ha.

For trees with less dense canopies or table grapes use adjustable nozzles (e.g. the “Butterfly”) fitted with the correct orifice plate to deliver the required volume. Adjust the nozzle to apply in a narrow cone (0.5–0.75 m band) directed upwards into the tree canopy. For table grapes the cone should be narrowed to apply towards the leaf canopy above the bunch line. These types of nozzles can also be used to apply a solid stream (not recommended for table grapes) providing that the correct orifice plates are used to meet the requirements as suggested for dense canopies above.

**NB:** Consult a bait distributor or pest management advisor for more details.

Placement of the correct-sized bait droplets in the correct area of the target plant is critical to success! Coarse droplets can be delivered by hand-lances with large nozzle holes and whirl-plates removed, under low pressure. An easily-maneuverable rig is preferable. An ideal rig is a 4-wheel motorcycle pulling a tank with hand lances or with fixed nozzles as described above. (See Annexure 5.)

**Water pH**

Test the **pH of the water** to be used and of the final mixture. If necessary use a buffering agent to achieve a pH of between 5.6 and about 6.5.
The pH of the bait solution is critical. The optimum pH for mercaptothion is 5.6, at which level it is most stable. Above this level it will break down more rapidly and become increasingly ineffective.

### Rain after baiting

If it rains more than 5 to 10 mm within 24 hours of application of mercaptothion + protein bait, repeat the application. GF-120 is more rain-fast – consult the distributor or a pest management practitioner.

### Bait applications during winter

During winter, continue with fortnightly ground-based bait applications in home gardens and other hotspots on warm, sunny days. During mild and dry winters, additional applications are required.

Fruit fly populations decline naturally in winter when the low temperatures (and wet conditions in the Western Cape) result in a relatively high natural mortality. This period in the season is therefore an ideal time to greatly reduce overwintering populations through baiting, so that spring populations are at a very low level when the season begins.

During warm and dry winters mortality is lower and many more flies survive through to spring, resulting in higher summer populations. Additional baiting is necessary under these conditions.

### Tank mixes

Do not allow bait solution to stand over in the tank until the following day.

Hydrolysis of the bait mixture will cause it to lose much of its efficacy by the next day.

### Bait application equipment used for citrus

The use of bait application equipment used on citrus (e.g. the "Mantis" or "Ladybird") is not recommended on deciduous fruit unless the equipment is modified to deliver the required droplet size.

This equipment works adequately in citrus orchards where there is a lower fruit fly population pressure than on deciduous fruit. Experience indicates that these machines tend to give less effective control in deciduous fruit orchards, where higher populations of fruit fly generally occur, and for which the correct droplet size is essential.

### Aerial application of bait

The aerial application of concentrated fruit fly bait is a very effective manner of fruit fly population suppression. In South Africa the aerial application of the mercaptothion + protein bait is only registered for use on citrus. On deciduous fruit, only ground applications of this type of bait are permissible. However, GF-120 is registered for aerial application on all fruit kinds.

#### Aerial application of GF-120 (based on Spinosad 0.24 g/L):

- **GF-120 NF**: 1 litre
- **Water**: 1 to 3 litres
- **Application rate**: 2 to 4 litres/ha

Aerial applications must be made with the correct equipment. Details on the type of dispensing tubes and swathe width etc. should be obtained from the GF-120 distributor.
Minimum/maximum residue levels (MRLs)

As export MRLs are constantly being revised, export fruit producers must ensure that they comply with the latest MRLs. It is incumbent on export fruit growers to acquaint themselves with the latest MRLs required for countries to which their fruit may be exported. In this regard consult the Industry Guideline Information on Restrictions on the Use of Plant Protection Products on the Deciduous Fruit Producers’ Trust internet site, www.deciduous.co.za.

SIT is a "numbers game" – there need to be 80 to 100 sterile males for every wild male in the target area for it to be effective. Unless the wild fruit fly population is reduced to low levels before releases start, the sterile males are unlikely to be able to compete against the very many wild males for mating with the females.
9. FRUIT FLY HOTSPOTS

Hotspots are those trap localities where trap catches are consistently high (about 1 FTD or higher), and which do not appear to respond to the normal population reduction baiting programme. This indicates that one or more of the sanitation/hygiene programme, the host plant management programme and the normal baiting programme are inadequate, or that there is an influx of wild flies from an adjacent area. These areas need additional attention.

**Hotspot identification**

Identify areas with **consistently high fruit fly trap catches**. Inspect the area for fruit fly hosts that may have been overlooked in the baiting or host plant management programme. Look for unusual wild hosts (e.g. wild berries) outside commercial plantings, and include them in the host plant management and baiting programmes. Review sanitation and hygiene actions.

There are various wild plant species that are not obvious fruit fly host plants that can easily be overlooked. Also bear in mind that many table grape cultivars, when ripe, can support full development of fruit fly larvae, as can “na-trossies”, especially when the berries start to dry out.

**Identifying unknown fruit fly breeding locations**

If consistently high fruit fly catches persist in an area and there is no obvious source immediately noticeable, hang additional traps in a 50 m to 100 m wide circle around that site. This is called delimitation.

Delimitation will usually pinpoint the direction from which fruit fly infestation is coming. When this has been identified the infestation source can be narrowed down and appropriate action taken.

**Aggressive baiting of hotspots**

Adopt a more aggressive baiting programme in hotspot areas; e.g. apply bait to a greater area in that trap locality, or apply bait twice a week (only in home gardens), or both. NB: Twice-weekly baiting with the mercaptothion + protein mixture should not be carried out in commercial orchards due to the risk of exceeding Maximum Residue Levels.

Keep a close watch on weekly trap counts in a hotspot locality, and maintain an aggressive baiting policy until fruit fly numbers are under control.

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For success in any fruit fly control programme, fruit flies must be controlled in their breeding grounds, and early in the season.
WHEN STERILE FLY RELEASES BEGIN

10. REVISION OF RESOURCES AND ACTIVITIES

Just before the releases of sterile flies are due to start, certain changes in strategy and equipment need to be made.

Map grids

Trapping grids on all maps should be changed from 25-ha grids to 49-ha (700 m x 700 m) grids.

In accordance with international protocol, the density of traps after the start of releases will be reduced from 1/25 ha to 1/49 ha. Traps should continue to be rotated as described in Section 5 above.

Choice, density, placement and maintenance of traps

Trap type: Replace Yellow Delta fruit fly traps with Chempac bucket-type traps baited with the 3-component lure that also catch females.

These traps are so-called “dry traps”; flies are not caught on a sticky pad as with male-only traps, but are retained in the semi-closed trap by a fumigant which kills them.

The detection of wild female fruit flies during this phase of the programme is crucial, as the presence of fertile females is the real danger in an SIT programme. If male-only traps had been used, they would have caught high numbers of expensive sterile males that should rather be free to mate with fertile females.

Trap density: In orchards and vineyards, place traps at a density of 1 trap per 49-ha block and record the geographical coordinates using GPS. Positions of traps can again be indicated on the operations room maps, and should also be marked on the digitized GIS maps.

In towns, trap density should be about 1 trap per 5 to 10 ha, and in natural vegetation around the perimeter of the SIT area, about 1 trap per 50 to 75 ha.

Trap placement, maintenance and rotation should be carried out as described in Section 5, with the following exception:

Trap placement for ground releases: Move all traps about 30 to 50 m away from home gardens into adjacent vineyards, orchards or other suitable trees.

Because most releases of sterile flies will take place in home gardens and backyards during ground releases, traps should be moved about 30 m away from these gardens into nearby vineyards, orchards or other suitable trees. If they remain in the home gardens they will trap large numbers of sterile flies which are needed to maintain the high sterile: wild ratio of fruit flies for successful SIT.

Yellow Delta traps (trimedlure): When doing aerial releases, retain 1 male-only trap per approximately 150 ha as a means of monitoring the uniform aerial dispersal of sterile males over the target area.

Trap maintenance: Follow the manufacturer’s guidelines for maintenance of both male-only traps and the female traps.

Host plant management and sanitation

Effective host plant management and sanitation as described in Section 8 must be continued after releases of sterile fruit flies start.

Any fruit, wild, domestic or commercial, in which fruit flies can breed will be a severe threat to the success of the SIT programme. Fruit flies can breed in even small berries – it is critical that all potential
breeding hosts and sites be identified, giving an early warning of infestation, and eliminated as far as possible.

**Bait applications**

**NB:** By now the wild fruit fly population should have been reduced to an annual average of less than 1 FTD by the fruit fly population reduction programme (see Section 8). If FTDs are higher than 1, the release of sterile flies is unlikely to be effective.

**Cease all area-wide bait applications**

(i.e. of orchards and vineyards) in the target area. Instead, aggressively bait all gardens and hotspot areas only, until no more wild flies are recorded in those areas.

At levels of less than 1 FTD the wild fruit fly population should be a much-reduced threat to fruit in orchards and vineyards.

Bear in mind that SIT is never a stand-alone technique and should ALWAYS be integrated with other appropriate methods including baiting, sanitation and host plant management.

The use of bait sprays is compatible with an SIT programme, as they will unselectively kill both sterile and wild flies. The ratio of sterile to wild fruit flies, which is all-important in an SIT programme, will therefore not be significantly altered.

**Fruit sampling**

When progressing from fruit fly suppression to the creation of low fruit fly prevalence areas, appoint sufficient fruit samplers to collect and monitor potentially-infested fruit for possible fruit fly emergence. This task could be accomplished by monitors and/or identification technicians (see below), depending on their work-load.

Early detection of fruit fly infestation in fruit is essential in any programme to create fruit fly-free or areas of low fruit fly prevalence, as it serves as an early warning of problems before the adult flies emerge and get caught in traps.

Fruit sampling is essential when creating areas of low fruit fly prevalence. It i) allows the early detection of fruit fly infestation; ii) enables the identification of primary and secondary fruit fly host plants during different seasons of the year; iii) allows a better understanding of fruit development of fruit fly host plants in relation to different climatic conditions; and iv) helps to evaluate the success of the SIT programme.

**Fruit sampling:** Each week collect 5 to 10 fruit (depending on size), both off plants and fallen fruit on the ground, from 20 25-ha trapping quadrants per area, two samples per quadrant. In the laboratory place fruit in buckets or other suitable containers, noting the quadrant and date, and keep in a room maintained at approximately 25°C. Inspect the containers daily for fruit fly larvae. The detection of even a single larva indicates a hotspot and should trigger an immediate control action (e.g. baiting, sanitation, fruit stripping) in that quadrant. After even a single larva has been detected from any sample, it is not necessary to continue monitoring that sample and it should be destroyed. With successive samplings every quadrant in the whole area should be sampled in this way every 3 months.

The same basic principles of SIT and pest management still apply after sterile releases start: effective monitoring, effective baiting, effective host plant management, effective sanitation.
11. STERILE FLY RELEASE TECHNIQUES

Success with an SIT programme is dependent on being able to maintain a ratio of sterile males to wild males in the field of at least 80:1, in order to minimize the chance of a wild male mating with a wild female. To achieve this the wild fruit fly population levels must first have been drastically reduced (see Section 6).

Routine releases of sterile fruit flies should only begin once the wild fruit fly population has been reduced to very low levels, typically an annual average of less than 1 FTD. Start in late winter/early spring to coincide with the naturally low levels of wild fruit flies at this time. Sterile fruit flies should be released at least weekly; twice-weekly releases are even better.

SIT Africa will supply sterile fruit flies in the form of either pupae dyed with a fluorescent dye, or sexually mature adults in paper bags, depending on the distance of the release area from the Medfly facility and the release method.

Besides the sterile flies, the paper bags will contain food in the form of agar, and a crumpled paper ball for additional resting space for the flies. If pupae are supplied, the SIT team in that area will need to place them in paper bags with agar and paper balls and maintain them at a suitable temperature and humidity until the flies have emerged and have matured for at least 4 days. Only then should the flies be released.

One of three methods can be used – ground releases with sterile flies in paper bags, aerial releases using a light aircraft, or a combination of ground and aerial releases.

Ground releases strategy

The recommendations below are based on experience with the ground release fruit fly SIT programmes in Chile and Mexico.

- Start the weekly ground release programme in July.
- Release the flies on the same day of each week.
- Complete releases before the heat of the day, e.g. before about 10:30 in summer; later in cooler weather.
- Release at least one bag of 5000 flies per hotspot (e.g. garden) per week, depending on the size of the hotspot. Larger gardens should receive more than one bag.
- Identify 5 or 6 dense trees with large leaves and good shade per release site.
- Each week release each bag of flies in three suitable trees/bushes per hotspot as follows:
  - At the 1st tree, open bag under the tree, release a small 'cloud' of flies; close bag.
  - At the 2nd tree, release another cloud of flies and place the paper ball with flies in a fork in that tree.
  - At the 3rd tree, tear open bag and leave it and the remaining flies in the tree.
- Do not place flies on the ground, on a fence, or in the direct sun.
- At the next release date choose three of the other suitable trees at each site. Remove any paper balls and bags from the previous release.
- Alternate release trees each week.

Ground releases (‘targeted releases’) are specifically aimed at home gardens and backyards (in towns and on farms) and other fruit fly hotspots in the target area. These are the breeding grounds of fruit flies – the great majority of fruit flies occur and breed in these areas until the commercial fruit crops ripen and become attractive to fruit flies, when they will start
migrating to these crops. The objective of ground releases is to suppress fruit fly populations in their breeding grounds early in the season before the commercial fruit ripens.

**Combined ground and aerial release strategy**

Initiate ground releases as described above and continue until the end of December. From the beginning of January, start aerial releases (see recommendations above) and continue until June and then revert back to ground releases in hotspots and fruit fly breeding grounds until the following January. Contact SIT Africa for further details if necessary.

**Combined ground and aerial releases**

Aerial releases later in the season are designed to protect the commercial crops from any wild flies that move from their breeding grounds to ripening commercial fruit.

Where the size of the area justifies the cost of using a light aircraft for releases, aerial releases should start in early spring when wild fruit fly populations are naturally low, and after an effective baiting and host plant management programme. Aerial releases are generally more effective than ground releases as they cover an entire target area ('blanket releases'), but unless the area is large (e.g. ±30 000 ha or more), they are not likely to be cost-effective due to the high cost of hiring the aircraft.

**Aerial release strategy**

A crucial element in the sterile fly release programme is to get the highest quality sterile males into the field so that they can effectively compete with the wild males. Release techniques can have a major impact on sterile male quality.
12. TRAP INSPECTION AND FRUIT FLY COLLECTION

Inspect each trap once a week, on the same day of the week where possible. Carefully remove all fruit flies and any other insects and place them in a suitable sealable vial, taking care that wind does not blow any away. Use a small paintbrush to remove all flies that may be loosely stuck in the bottom of the trap. Mark the trap number on the vial, and deliver all flies on the same day to the SIT laboratory for identification.

As "dry traps" are used at this stage of the programme, all flies will be easily transferred from the trap to a vial.

13. STERILE FLY IDENTIFICATION, DATA MANAGEMENT, AND REVIEW OF PROGRESS

Sterile fly identification

In a darkened cubicle or room in the operations centre, individually inspect all fruit flies trapped in female traps to i) determine the species, ii) whether they are fertile or sterile, iii) their sex, and, if necessary, iv) their mating status.

Sterile male Medflies are identified on the basis of the presence of fluorescent dye applied in the pupal stage when they are observed under a microscope and ultraviolet light in a laboratory. Determining the presence of wild females, and also their mating status when creating an area of low prevalence, is essential in order to assess the success of the SIT programme. Knowledge of the presence of any other fruit fly species (e.g. Natal fruit fly) is also crucial.

These are specialised tasks for which equipment (see Section 2) and training is needed. Training can be given by SIT Africa, or ARC Infruitec-Nietvoorbij (see "Contact details for further information" at the end of this manual).

Recording data

Enter each week’s trap catch data into a proforma SIT Africa spreadsheet and generate graphs as mentioned in 7. above. The graph should include the wild flies, sterile flies, and data on any other fruit fly species encountered.

Monitoring progress of the SIT programme

Success with the routine releases of sterile fruit flies is measured primarily by i) the number of wild fruit flies caught in monitoring traps, ii) the number of traps capturing sterile males, and iii) the number of infested fruit in the fruit samples.

In a fruit fly suppression programme, an indication of reasonably good success would be an average of 1 FTD or less over a year; at the same time FTDs during the peak of the fruit fly season (December to May, depending on the area) should not exceed this level. Sterile males should be recorded in at least 80% of the traps, and ideally there should be no infested fruit in the samples.

For areas of low fruit fly prevalence, average FTDs of between 0.001 and 0.0001 and lower over a year would indicate success. For fruit fly-free areas, the FTD should be 0 for at least 12 months.

Failure to address any of the standard procedures will most likely result in higher wild fruit fly populations than given above, and in infested fruit in the samples.

Accurate differentiation between sterile flies and wild flies, and between males and females, is crucial in an SIT programme.
RECOMMENDATIONS AT A GLANCE

As a quick-reference guide, all boxed recommendations given above are repeated below without any additional explanation. However, before making decisions users of this Manual should refer to the explanations given in the relevant part of the Manual.

### PREPARATION FOR STERILE FLY RELEASES

#### 2. INFRASTRUCTURE AND RESOURCE DEVELOPMENT (see p4)

**Operations centre**

Set up a single operations centre for each area, fully equipped with the necessary office and communication equipment, from which all actions, pre- and post-sterile fly releases, will be centrally coordinated over the area.

**Maps**

In the operations centre display maps of the area (e.g. 1:10 000 aerial maps/photos), including urban areas, with 25-ha referenced grids, in the operations centre (see example in Annexure 1). Digitized GIS maps should also have 25-ha grids.

**Staffing**

- **SIT Area coordinator:** Appoint a full-time SIT Area Coordinator. One full-time Assistant SIT Coordinator is advised for larger areas, e.g. 10,000 ha and more.
- **Fruit fly monitors:** Appoint full-time fruit fly monitors; one monitor for between about 100 to 120 fruit fly traps, depending on terrain.
- **Bait application contractors:** Appoint a bait application contractor to ensure that all commercial fruit and other fruit fly host plants in the target area can be regularly baited according to the prescribed programme (see Sections 8, 9 & 10).
- **Host plant/sanitation manager:** The appointment of a person to coordinate host plant management and sanitation is highly recommended.

**Public relations:** An effective public relations function for the SIT programme must be established to continually keep all stakeholders up to date with all activities and outcomes in all SIT areas.

**Identification technicians:** One or more fruit fly identification technicians will have to be appointed to identify and count all fruit flies caught in the traps. Once releases of sterile fruit flies have started, wild and sterile fruit flies from all weekly trap catches will also need to be identified and counted.

**Equipment and consumables**

Besides the necessary climate-control equipment (see under "Operations centre" above), the following should be acquired: monitoring traps and lures (see Sections 4 and 10), fruit fly bait and bait application equipment (see Section 8 iii), a suitable GPS instrument, a stereo microscope, insect dissecting equipment, magnifying glasses (head-mounted and/or hand-held), vials, buckets for fruit-sampling.

After sterile releases begin, the following will also need to be procured: racks for storing bags of sterile flies, and a good ultra-violet light for the identification of dyed sterile fruit flies. These identifications need to be made in a darkened environment (e.g. in a well-shaded or curtained cubicle) to enhance the visibility of the dyed flies. Equipment and raw ingredients to prepare food (e.g. agar) for the emerging sterile flies will also be needed.
3. **HOST PLANT IDENTIFICATION** (see p7)

**Identify all non-commercial fruit fly hosts** in and around the SIT area. Record their positions by GPS, and enter these positions on the digitized GIS maps. See Section 6.

Maintain a **host plant database** containing details of all types of fruit fly host plants, both obvious (home garden fruit trees) and less obvious (e.g. wild berries, rose hips), and their locality and fruiting times.

4. **CHOICE OF FRUIT FLY TRAP** (see p8)

**Male traps and lures:** For monitoring fruit fly populations before the release of sterile fruit flies, SIT Africa requires that only "Yellow Delta" traps and lures be used. See Annexure 3.

5. **TRAP INSTALLATION AND MAINTENANCE** (see p9)

**Trap density:**
In orchards and vineyards, place Yellow Delta traps at a density of 1 trap per 25-ha block. The current GPS position of the trap in each block must be indicated on maps in the operations centre, and must also be marked on the digitized GIS maps.

In **towns**, trap density should be about 1 trap per 5 to 10 ha, and in **natural vegetation** around the perimeter of the SIT area, about 1 trap per 50 to 75 ha.

Clearly number each trap using a permanent marker for data recording purposes. Each trap number must remain permanently associated with the same 25-ha quadrant.

**Lures:** Place the lure on the glue in the centre of the trap bottom, and ensure that it is not covered with gum.

**Trap maintenance:** Maintain traps and replace lures strictly according to the manufacturer's specifications.

**Trap rotation:** If any trap records zero catches for more than a couple of weeks while other traps nearby are trapping fruit flies, move this trap 100 to 200 m away in the same 25-ha block every 4 to 6 weeks. Record any new trap positions on the GIS system and on the aerial photos in the operations centre.

6. **USE OF GPS AND GIS** (see p10)

**Position of fruit fly traps**

The geographical coordinates of each trap should be recorded using a GPS instrument and downloaded into a GIS programme. SIT Africa will coordinate this activity.

**Location of host plants; other data**

The geographical coordinates of each host plant or group of host plants should also be recorded by GPS and downloaded into a GIS programme. If the type of GPS instrument allows, record also details such as host plant type and ripening times.

7. **TRAP INSPECTION, FRUIT FLY IDENTIFICATION, AND DATA RECORDING & MANAGEMENT** (see p11)

**Trap inspection and fruit fly identification**

Inspect each trap once a week, on the same day of the week where possible. Carefully remove all fruit flies and any other insects or debris, taking away as little glue as possible. Record the number of wild Medflies, and the number and identity of any other species of fruit fly (e.g. Natal fruit fly) separately. Stir the remaining glue with a thin stick to ensure that the trap remains effective.

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**Data recording and management**

Enter each week’s trap catch data into a proforma SIT Africa spreadsheet. Generate graphs of Medfly trap catches per week for the whole area as well as sub-areas, standardizing the units on the y-axis to the average number of fruit flies per trap per day (FTD). The occurrence of any other fruit fly species should be included separately on the same graph.

SIT coordinators should send the weekly trap catch data as soon as possible to SIT Africa. SIT Africa will collate all the data and regularly provide each SIT area with a GIS map indicating wild fly population densities.

### 8. FRUIT FLY POPULATION REDUCTION PROGRAMME (see p12)

**i) Sanitation and hygiene**

Remove and destroy (e.g. by pulping, or placing in black plastic bags left in the sun), or bury at least 1 m deep, all fruit fly-infested and fallen fruit. In vineyards, the removal of “na-trossies” is highly advisable. Pay particular attention to home gardens. Where the fruit will not be used it is strongly recommended that it is completely stripped from trees when still immature.

**ii) Host plant management**

Remove, bait or strip fruit from all identified fruit fly host plants, taking into consideration the fruiting times where this has been determined. Domestic fruit trees from which fruit is never usable due to fruit fly infestation should ideally be cut down. "Na-trossies" in commercial vineyards should be removed and destroyed as far as possible. See "i) Sanitation and hygiene" above, Section 3 and Annexures 2 and 4).

Between October and end of May hang four to six M3 bait stations per host or shade tree, replacing them every 3 months.

**Bait recipes**

**Bait recipe #1 (GF-120, based on Spinosad 0.24 g/L):**

GF-120 NF: 1.0 – 1.2 litres, plus:

- Citrus and deciduous fruit:
  - Water: 19 – 29 litres
  - Application rate: 20 – 30 litres/ha

- Table grapes and other crops:
  - Water: 9 – 30 litres
  - Application rate: 10 – 30 litres/ha

- Home gardens:
  - Water: 9 – 10 litres
  - Application rate: 2 – 3 litres/garden

**NB:** GF-120 should only be applied with special equipment – see "Ground-based bait application equipment" below. The same equipment can be used for both GF-120 and protein hydrolysate baits.

**Bait recipe #2 (mercaptothion and protein):**

- Mercaptothion 50% EC: 500 ml
- Protein hydrolysate: 2 litres
- Water: 100 litres
- Application rate: 50 – 75 litres/ha
  
  (= 125 – 187.5 ml mercaptothion a.i./ha)

**Ground-based bait application**

- Apply routinely in a coordinated manner according to the prescribed programme. Application intervals change during the season, from weekly during the growing season to fortnightly during winter. Consult SIT Africa or ARC Infruitec-Nietvoorbij.
- Apply in scattered coarse droplets of 1 to 4 mm diameter for bearing trees (to minimize fruit spotting), and 4 to 6 mm for non-bearing trees, post-harvest, or non-commercial shrubs and trees. Larger droplets are more attractive to fruit flies, and the active ingredients stay effective for longer than in smaller droplets.
- Aim the bait to the southeast quadrant of the tree, in an upwards direction to place it in the centre of the tree, under the leaves where the flies tend to congregate and mate, and where the bait is protected from rain and UV light.
Apply in the early morning (so that it is the fruit fly's first meal of the day).
- Under conditions of heavy early morning dew, rather apply the bait later in the day.

Bait application sites
- Apply to all host plants and trees/shrubs with good leaf coverage that provide good shelter to fruit flies, especially in gardens and backyards, over the entire SIT area; the larger the area treated, the greater the efficacy.
- Apply to commercial plantings according to registered recommendations – consult the bait distributor, SIT Africa or ARC Infruitec-Nietvoorbij.

Ground-based bait application equipment
Only use equipment that will apply the bait in the required-sized droplets. **Mistblowers or other equipment delivering fine droplets should not be used**, unless they can be modified to deliver large droplets under low pressure.

For citrus or trees with dense canopies preferably use equipment that applies a thin, solid stream (e.g. spraying systems D1 – D3 nozzle tips without whirl plates) at a pressure of 2-3 bar, aimed upwards into the centre of the tree canopy. When the thin stream strikes any obstruction at the suggested pressure, it will break up into droplets of the desired size inside the canopy. Use as many nozzles as necessary to meet the required delivery per ha.

For trees with less dense canopies or table grapes use adjustable nozzles (e.g. the “Butterfly”) fitted with the correct orifice plate to deliver the required volume. Adjust the nozzle to apply in a narrow cone (0.5-0.75 m band) directed upwards into the tree canopy. For table grapes the cone should be narrowed to apply towards the leaf canopy above the bunch line. These types of nozzles can also be used to apply a solid stream providing that the correct orifice plates are used to meet the requirements as suggested for dense canopies above.

**NB:** Consult a bait distributor or pest management advisor for more details.

Water pH
Test the **pH of the water** to be used and of the final mixture. If necessary use a buffering agent to achieve a pH of between 5.6 and about 6.5.

Rain after baiting
If it rains more than 5 to 10 mm within 24 hours of application of mercaptothion + protein bait, repeat the application. GF-120 is more rain-fast – consult the distributor or a pest management practitioner.

Bait applications during winter
During winter, continue with fortnightly ground-based bait applications in home gardens and other hotspots on warm, sunny days. During mild and dry winters, additional applications are required.

Tank mixes
Do not allow bait solution to stand over in the tank until the following day.

Bait application equipment used for citrus
The use of bait application equipment used on citrus (e.g. the “Mantis” or “Ladybird”) is not recommended on deciduous fruit unless the equipment is modified to deliver the required droplet size.

Aerial application of bait

**Aerial application of GF-120 (based on Spinosad 0.24 g/L):**
- GF-120 NF: 1 litre
- Water: 1 to 3 litres
- Application rate: 2 to 4 litres/ha
  (1L GF-120 formulation/ha)

Minimum/maximum residue levels (MRLs)

As **export MRLs** are constantly being revised, export fruit producers must ensure that they comply with the latest MRLs. It is incumbent on export fruit growers to acquaint themselves with the latest MRLs required for countries to which their fruit may be exported. In this regard

### 9. FRUIT FLY HOTSPOTS (see p18)

#### Hotspot identification and location

<table>
<thead>
<tr>
<th>Information</th>
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<tbody>
<tr>
<td><strong>Identifying unknown fruit fly breeding locations</strong></td>
<td>If consistently high fruit fly catches persist in an area and there is no obvious source immediately noticeable, hang additional traps in a 50 m to 100 m wide circle around that site. This is called delimitation.</td>
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<tbody>
<tr>
<td><strong>Aggressive baiting of hotspots</strong></td>
<td>Adopt a more aggressive baiting programme in hotspot areas; e.g. apply bait to a greater area in that trap locality, or apply bait twice a week (only in home gardens), or both. NB: Twice-weekly baiting with the mercaptothion + protein mixture should not carried out in commercial orchards due to the risk of exceeding Maximum Residue Levels.</td>
</tr>
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</table>

#### FRUIT FLY HOTSPOTS

**Hotspot identification and location**

Identify areas with **consistently high fruit fly trap catches**. Inspect the area for fruit fly hosts that may have been overlooked in the baiting or host plant management programme. Look for unusual wild hosts (e.g. wild berries) outside commercial plantings, and include them in the host plant management and baiting programmes. Review sanitation and hygiene actions.

**Identifying unknown fruit fly breeding locations**

If consistently high fruit fly catches persist in an area and there is no obvious source immediately noticeable, hang additional traps in a 50 m to 100 m wide circle around that site. This is called delimitation.

**Aggressive baiting of hotspots**

Adopt a more aggressive baiting programme in hotspot areas; e.g. apply bait to a greater area in that trap locality, or apply bait twice a week (only in home gardens), or both. NB: Twice-weekly baiting with the mercaptothion + protein mixture should not carried out in commercial orchards due to the risk of exceeding Maximum Residue Levels.

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### WHEN STERILE FLY RELEASES BEGIN

#### 10. REVISION OF RESOURCES AND ACTIVITIES (see p19)

**Map grids**

- **Trapping grids** on all maps should be changed from 25-ha grids to 49-ha (700 m x 700 m) grids.

**Choice, density, placement and maintenance of traps**

<table>
<thead>
<tr>
<th>Information</th>
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<tbody>
<tr>
<td><strong>Trap type:</strong> Replace Yellow Delta fruit fly traps with Chempac bucket-type traps baited with the 3-component lure that also catch <strong>females</strong>.</td>
<td></td>
</tr>
<tr>
<td><strong>Trap density:</strong> In orchards and vineyards, place traps at a density of 1 trap per 49-ha block and record the geographical coordinates using GPS. Positions of traps can again be indicated on the operations room maps, and should also be marked on the digitized GIS maps.</td>
<td></td>
</tr>
</tbody>
</table>

In towns, trap density should be about 1 trap per 5 to 10 ha, and in natural vegetation around the perimeter of the SIT area, about 1 trap per 50 to 75 ha.

**Trap placement for ground releases:** Move all traps about 30 to 50 m away from home gardens into adjacent vineyards, orchards or other suitable trees.

**Yellow Delta traps (trimedlure):** When doing **aerial releases**, retain 1 male-only trap per approximately 150 ha as a means of monitoring the uniform aerial dispersal of sterile males over the target area.

**Trap maintenance:** Follow the manufacturers guidelines for maintenance of both male-only traps and the female traps.
Host plant management and sanitation

Effective host plant management and sanitation as described in Section 8 must be continued after releases of sterile fruit flies start.

Bait applications

Cease all area-wide bait applications (i.e. of orchards and vineyards) in the target area. Instead, aggressively bait all gardens and hotspot areas only, until no more wild flies are recorded in those areas.

Fruit samplers and fruit sampling

When progressing from fruit fly suppression to the creation of low fruit fly prevalence areas, appoint sufficient fruit samplers to collect and monitor potentially-infested fruit for possible fruit fly emergence. This task could be accomplished by monitors and/or identification technicians (see below), depending on their work-load.

Fruit sampling: Each week collect 5 to 10 fruit (depending on size), both off plants and fallen fruit on the ground, from 20 25-ha trapping quadrants per area, two samples per quadrant. In the laboratory place fruit in buckets or other suitable containers, noting the quadrant and date, and keep in a room maintained at approximately 25°C. Inspect the containers daily for fruit fly larvae. The detection of even a single larva indicates a hotspot and should trigger an immediate control action (e.g. baiting, sanitation, fruit stripping) in that quadrant. After even a single larva has been detected from any sample, it is not necessary to continue monitoring that sample and it should be destroyed. With successive samplings every quadrant in the whole area should be sampled in this way every 3 months.

11. STERILE FLY RELEASE TECHNIQUES
(see p21)

Ground release strategy

- Start the weekly ground release programme in July.

- Release the flies on the same day of each week.
- Complete releases before the heat of the day, e.g. before about 10:30 in summer; later in cooler weather.
- Release at least one bag of 5000 flies per hotspot (e.g. garden) per week, depending on the size of the hotspot. Larger gardens should receive more than one bag.
- Identify 5 or 6 dense trees with large leaves and good shade per release site.
- Each week release each bag of flies in three suitable trees/bushes per hotspot as follows:
  * At the 1st tree, open bag under the tree, release a small 'cloud' of flies; close bag.
  * At the 2nd tree, release another cloud of flies and place the paper ball with flies in a fork in that tree.
  * At the 3rd tree, tear open bag and leave it and the remaining flies in the tree.
- Do not place flies on the ground, on a fence, or in the direct sun.
- At the next release date choose three of the other suitable trees at each site. Remove any paper balls and bags from the previous release.
- Alternate release trees each week.

Aerial release strategy

Release between 500 and 1000 sterile males per hectare, depending on circumstances, and particularly on the wild fly FTDs in the area. Twice-weekly aerial releases over the whole area, starting in early spring, are recommended. Planning and execution of aerial releases is intricate, is GPS-based and needs to be well planned. SIT Africa will plan and coordinate this activity.

Combined ground and aerial release strategy

Initiate ground releases as described above and continue until the end of December. From the beginning of January, start aerial releases as described above, continue until June and then revert back to ground releases in hotspots and fruit fly breeding grounds until the following January. Contact SIT Africa for further details if necessary.
12. TRAP INSPECTION AND FRUIT FLY COLLECTION (see p23)

Inspect each trap once a week, on the same day of the week where possible. Carefully remove all fruit flies and any other insects and place them in a suitable sealable vial, taking care that wind does not blow any away. Use a small paint brush to remove all flies that may be loosely stuck in the bottom of the trap. Mark the trap number on the vial, and deliver all flies on the same day to the SIT laboratory for identification.

13. STERILE FLY IDENTIFICATION, DATA MANAGEMENT, AND REVIEW OF PROGRESS (see p23)

Sterile fly identification

In a darkened cubicle or room in the operations centre, individually inspect all fruit flies trapped in female traps to i) determine the species, ii) whether they are fertile or sterile, iii) their sex, and, if necessary, iv) their mating status.

Recording data

Enter each week's trap catch data into a proforma SIT Africa spreadsheet and generate graphs as mentioned in 7. above. The graph should include the wild flies, sterile flies, and data on any other fruit fly species encountered.

Monitoring progress of the SIT programme

Regularly review graphs and GIS maps of wild and sterile fruit fly populations in all areas.
CONTACT DETAILS FOR FURTHER INFORMATION:

<table>
<thead>
<tr>
<th>Dr Brian Barnes</th>
<th>Mr Ian Sutherland</th>
</tr>
</thead>
<tbody>
<tr>
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<td>082 803 3812</td>
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<td><a href="mailto:ian@sitafrica.co.za">ian@sitafrica.co.za</a></td>
</tr>
</tbody>
</table>
Annexure 1

GPS, GIS, mapping and data management

Example of a GPS instrument used for geo-referencing e.g. trap sites and host plant localities.

Aerial photo of a fruit production area, showing subdivision of the area into blocks to facilitate trap placement.
Annexure 1 (cont.)

GIS map created from data collected on a GPS instrument illustrating different sized fruit fly populations in different localities with different sized red dots. (Acknowledement: M. Silva)

Example of a graph of average fruit fly trap catches in an SIT area
Annexure 2

Fruit fly host plants

Medfly and Natal fruit fly will infest all deciduous fruits and table grapes, all citrus fruits, and a great many other fruits of trees or shrubs, wild or domestic, but to differing degrees. At the one end of the scale, guava, loquat, peach and wild plum (*Harpephyllum caffrum*) are examples of fruits which are very readily infested fruit fly, while at the other end of the scale, lemon, avocado and olive are examples of fruit with very low infestation potential.

Various lists of the very extensive number of host plants of Medfly have been published. Some examples:

- **Fruit Flies of Economic Significance: Their Identification and Bionomics**, by I.M. White & M.M. Elson-Harris (1994; p291);
- **Bionomics and control of the fruit flies, Ceratitis capitata (Wied.) and Pterandrus rosa (Ksh.),** in the Western Cape Province, by A.C. Myburgh (1956) – lists given for Medfly and Natal fruit fly;
- **Natal Fruit Fly, Ceratitis rosa Karsch (Insecta: Diptera: Tephritidae, by H.V. Weems, and T.R. Fasulo. [http://edis.ifas.ufl.edu/IN538](http://edis.ifas.ufl.edu/IN538).**

Hard-copy references are obtainable from the Plant Protection Division, ARC Infruitec-Nietvoorbij, Stellenbosch.

It will serve little purpose to list here every single host species documented by these various authors, as many either do not occur in South Africa, are only occasional or rare hosts, and/or are species which the average person using this Manual is unlikely to encounter. The selected list given in this Annexure is therefore intended mainly to illustrate the wide variety of fruits infested by Medfly and Natal fruit fly, but including all the more common host fruits as well as some less common examples. Fruit flies have been recorded from many wild species of indigenous and exotic plants from a large number of families. For the purposes of an SIT programme it would probably be best to consider any unknown fruit or berry as a potential fruit fly host unless proven otherwise.

Fruit does not necessarily have to be large to serve as a fruit fly host fruit. For example, the author of this Manual has collected fruit flies from milkwood berries, which are only about 5 mm in diameter.

The host plants listed below have been taken from the above references and are divided into four categories – major commercial fruit hosts; other fruit trees, ornamentals and domestic hosts; other trees; and wild hosts. No attempt is made to indicate the relative degrees of susceptibility to fruit flies of these hosts, as this differs according to species of fruit and fruit fly, the specific locality, and can be subjective. However, some of the most susceptible include stone fruit, guava, loquat, quince and wild plum, *H. caffrum*. 
Annexure 2 (cont.)

Selected list of fruit fly host plants

Major commercial fruit hosts
Apple, apricot, avocado, citrus, coffee, date palm, grape, kiwi fruit, litchi, mango, nectarine, papaya, peach, pear, persimmon, plum, prune,

Other fruit trees, ornamentals and domestic hosts
Black nightshade, cherry solanum, crab apple, custard apple, fig, grenadilla, guava, kei apple, loquat, lowveld mangosteen, medlar, mulberry, Natal plum (num-num), pomegranate, prickly pear, quince, rose-apple, rose hip, Rubus spp. (brambleberry, youngberry etc.), strawberry guava, strawberry tree, tree tomato, wild asparagus

Other trees
Box thorn, bug tree, Cape ash, forest peach, ironwood, white milkwood, monkey orange, sandalwood, sapodilla, wild olive, monkey orange, wild plum, yellowwood.

Wild hosts
Either or both of the two fruit fly species have been recorded from wild hosts belonging to a large number of families, including: Anacardiaceae, Cecropiaceae, Chrysobalanaceae, Cucurbitaceae, Ebenaceae, Euphorbiaceae, Flacourtiaceae, Longanaceae, Malpighiaceae, Meliaceae, Myrtaceae, Oleaceae, Podocarpaceae, Rosaceae, Rubiaceae, Sapotaceae, and Solanaceae.
While some of these families may be absent or not well represented in South Africa, they are included to illustrate the very wide host range of Medfly and Natal fruit fly. There are likely to be even more wild host plant families with species susceptible to fruit fly infestation.

Some common fruit fly host plants

Loquat, *Eriobotrya japonica*  
Prickly pear, *Opuntia* sp.
Annexure 2 (cont.)

- Cape ash, *Ekebergia capensis*
- Crab apple, *Malus* sp.
- Rose hip, *Rosa* sp.
- Strawberry guava, *Psidium cattleianum*
- Yellowwood, *Podocarpus* sp.
- Wild plum, *Harpephyllum caffrum*
Brambleberry, *Rubus* sp.

Bugweed, *Solanum mauritianum*

Kei apple, *Dovyalis caffra*

Unharvested grapes in a vineyard
Annexure 3

Fruit fly traps

- Chempack trap
- Yellow Delta trap
- Multilure trap (photo USDA)
- Wing trap (Trécé)
- Jackson trap
Fruit fly sanitation and host plant management

Good sanitation and orchard and vineyard hygiene is crucial for effective fruit fly control. All unharvested fruit in vineyards and orchards, and fallen fruit in backyards, must be removed and buried at least a metre deep, or pulped. Alternatively, all unwanted or unusable fruit should be totally stripped from the trees when green (then no burying is necessary). Problem fruit trees should ideally be cut down.
Annexure 5

Bait application equipment

~ The main aim – large droplets directed upwards into the tree ~

Mist blower – nozzle holder removed. Thick stream, fan only.

Purpose-built bait applicator on quad bike; bait applied in impulses, directed up into the trees.

Quad bike; bait streams directed upwards into trees.

Back pack – All home gardens must be treated.

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Under favourable conditions female fruit flies become sexually mature and capable of laying eggs about 5 days after they emerge. After mating they actively seek out ripening fruit, and deposit their banana-shaped eggs in a small cavity just below the skin. Oviposition (sting) sites appear as small brown spots on the surface of the fruit, under which is a cavity with one to more than 20 eggs.

After 2 to 3 days in favourable conditions the minute, transparent larvae hatch and start feeding on the flesh of the fruit, slowly tunneling towards the core. The larvae have a sharply-pointed front end with no obvious head, and a blunt rear end, and become cream-coloured as they get older. Early infestation is often indicated by a brown colouration of the fruit flesh in the area of feeding due to oxidation of the tissues. From about 7 to 40 days later, depending on fruit kind and temperature, the larvae reach maturity (8 to 10 mm long), when they leave the fruit, fall to the ground and pupate just below the surface of the soil. About 8 to 40 days later, depending on temperature, the adult flies emerge from the pupae, crawl up to the soil surface, and the cycle is complete.

During warm conditions and in ripe fruit, the life cycle can be completed in as little as 3 to 4 weeks. This duration can increase to about 2 or 3 months in winter or where eggs are laid in greener fruit.