AREA-WIDE MANAGEMENT OF MEDITERRANEAN FRUIT FLY WITH THE STERILE INSECT TECHNIQUE IN SOUTH AFRICA: NEW PRODUCTION AND MANAGEMENT TECHNIQUES PAY DIVIDENDS

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SUMMARY

A mass-rearing facility to produce sterile male Mediterranean fruit flies, *Ceratitis capitata* (Wiedemann), for a Sterile Insect Technique (SIT) programme in the Hex River Valley in the Western Cape Province started in the late 1990s. The programme was initially underfunded and could only produce about 5 million sterile male flies per week. The resultant aerial release rate of 500 sterile males/ha/week reduced wild Mediterranean fruit fly populations substantially, but not to sufficiently low levels. Due to financial considerations, in 2003 aerial releases were replaced with ground releases targeting all gardens, other hotspots and neglected host plants. It was clear that with more funding, fruit fly mass-rearing facility and field operations could be improved, better quality control could be implemented, and more and better quality male sterile flies could be produced and released. Increased government support in 2001 resulted in a larger mass-rearing facility, and further improvements included the implementation of a quality control management system and the introduction of a new genetic sexing strain (VIENNA 8). The resultant increase in the production of sterile Mediterranean fruit flies of better quality enabled the SIT programme to be systematically introduced to additional fruit production areas. The Mediterranean fruit fly SIT programme was privatised in 2003 and is now operated by *FruitFly Africa (Pty) Ltd*. In 2009 a new approach to funding was adopted with a renewable Memorandum of Understanding (MoU) between the Department of Agriculture, Forestry and Fisheries (DAFF) and the deciduous fruit and table grape industry. Under the MoU, the DAFF provides 50% of the necessary funding, while 50% is collected from growers through statutory levies. In 2010 a new state of the art mass-rearing facility became operational and subsequent improvements in production processes and facility maintenance resulted in improved fruit fly production and quality. By 2016 sterile male production had increased to 56 million flies per week. After 12 years of ground releases of sterile Mediterranean fruit flies, aerial releases were resumed in three main production areas, and, at the time of writing, include approximately 15 000 ha of commercial deciduous fruit and table grapes. As a result of this well-funded area-wide integrated pest management (AW-IPM) programme, average wild Mediterranean fruit fly populations in the SIT areas have decreased by as much as 73%. The

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South African Mediterranean fruit fly SIT programme now aims to manage some of the fruit production areas as areas of low pest prevalence. Increased funding and a stable income stream also enabled *FruitFly Africa* to apply early detection and rapid response programmes for invasive pests such as *Bactrocera dorsalis* in relevant areas.

Key Words: Ceratitis capitata, *Ceratitis rosa, Ceratitis quilicii,* Tephritidae, SIT, public/private partnership, sterile male releases, suppression, Western Cape, Northern Cape, Eastern Cape

1. INTRODUCTION

The Western Cape Province is the centre of the South African deciduous fruit industry, followed by the Northern and Eastern Cape Provinces and to a lesser extent by smaller production areas in other provinces. Two fruit fly species of economic importance were previously recorded as occurring in the Western Cape, i.e. the Mediterranean fruit fly (*Ceratitis capitata* (Wiedemann)) and the Natal fruit fly (*C. rosa* Karsch) (Blomefield et al. 2015). However recent studies have revealed distinct morphological and molecular differences within populations of *C. rosa,* differentiated further by environmental requirements such as by temperature and altitude (Virgilio et al. 2013; Karsten et al. 2016). This resulted in the description of a new species viz. *Ceratitis quilicii* (De Meyer et al. 2016; FAO/IAEA 2019). Comprehensive surveys have not yet been conducted to determine the prevalence of either species. It can be deducted, however, from the studies of Karsten et al. (2016) that *C. quilicii* is more prevalent in the Western Cape than *C. rosa*.

Mediterranean fruit fly is the predominant species in most areas in the Western Cape (De Villiers et al. 2013; Manrakhan and Addison 2014) and is categorised as a quarantine pest for most of South Africa's export markets for deciduous fruit. Globally, more than 260 different fruit species, including citrus, are hosts of Mediterranean fruit fly, and it can cause enormous crop losses to commercially-produced fruit and also some vegetables if not controlled (USDA 2019). Small-scale farmers, as well as communities with backyard fruit trees, are also seriously affected by this species (White and Elson-Harris 1994).

Deciduous fruit (pome and stone fruit) and table grapes are mostly grown in mountain valleys in the Western and Eastern Cape, and in a semi-desert area alongside the Lower Orange River in the Northern Cape. The valleys are fairly isolated by surrounding mountains, and the Lower Orange River production area by the surrounding semi-desert area, making possible area-wide integrated pest management (AW-IPM) programmes incorporating the Sterile Insect Technique (SIT) covering a number of separate and relatively isolated areas.

South Africa is a net exporter of fruit and for many decades has had an established, well organised and integrated deciduous fruit industry, which in 2016 exported approximately 880 000 metric tons of deciduous fruit with an estimated value of USD 1200 million (DAFF 2017). The deciduous fruit industry in South Africa is one of the largest employers in horticulture, representing a significant investment both in terms of human resources and foreign exchange earnings (DAFF 2017). The country cannot afford to jeopardise future exports by allowing fruit flies to hinder international trade.

It is therefore essential for the South African export fruit industry to reduce fruit fly interceptions to a minimum to ensure market access and to reduce production losses. The European Union is the destination of more than 40% of fruit exports, and other markets include Japan, Taiwan and the USA (DAFF 2017). The European Union will intercept and detain fruit consignments for any non-European fruit fly larvae detected in fruit, which often includes unidentified larvae of the Mediterranean fruit fly, but also other *Ceratitis* spp., if the consignment does not originate from the European Union.

The use of chemical insecticides has become increasingly complex due to pest resistance, environmental concerns, and restrictions on residue levels by importing countries. In the interests of reducing insecticide use, as well as pre- and post-harvest crop losses, while maintaining sustainable agricultural systems, AW-IPM programmes integrating the SIT have proved effective in supporting safe and environment-friendly international trade.

South Africa is one of the largest deciduous fruit exporting countries in the southern hemisphere, but with a relatively small SIT programme to suppress or eradicate fruit flies. South Africa's major competitors on the international fruit export market, such as Chile, are either fruit fly-free, well advanced in achieving this or have at least low pest prevalence status. Use of the SIT, which has successfully contributed to eradicating the Mediterranean fruit fly in Chile and North America, as well as parts of Argentina, Australia, Peru, and Central America, has resulted in substantial savings to these countries (Enkerlin 2021).

A key factor for the success of any SIT programme is availability of adequate funding and long-term commitment of stakeholders. Funds generated from growers by making use of, e.g. a statutory grower levy, need to be supplemented with government funding in view of the public benefits of such programmes. Political will to support AW-IPM programmes which include the SIT is therefore needed to ensure sustainable funding (Dyck et al. 2021a).

2. HISTORIC OVERVIEW OF THE SOUTH AFRICAN SIT PROGRAMME

The Mediterranean fruit fly SIT programme in South Africa originated in 1996 when the Agricultural Research Council's (ARC) Infruitec-Nietvoorbij Institute for Fruit, Vine and Wine in Stellenbosch approached the Joint Food and Agriculture Organization of the United Nations (FAO)/International Atomic Energy Agency (IAEA) Programme of Nuclear Techniques in Food and Agriculture for technical support for a project to investigate the feasibility of integrating the SIT to suppress or eradicate Mediterranean fruit fly in the Hex River Valley. The pilot area was chosen mainly because of its relative geographic isolation, its large production area of 5000 ha of table grapes, a major export crop, and the fact that Mediterranean fruit fly was the dominant fruit fly pest (Barnes 2016).

Aerial releases of sterile Mediterranean fruit flies using a fixed-wing aircraft started in 1999, and flies were dispersed at a density of 500 sterile male Mediterranean fruit flies per ha per week. Wild Mediterranean fruit fly populations were subsequently reduced by 80% (Barnes et al. 2015), but still inadequately.

Nevertheless, encouraged by these early results, the governing body of the deciduous fruit industry, the then Deciduous Fruit Producers' Trust (DFPT, later HORTGRO) assisted the ARC with limited funding for the implementation of the project. Overall management of project funding at local level was through a formal 'SIT Partnership' agreement between the ARC and the DFPT. Additional funding in 2001 from the Western Cape Department of Agriculture allowed for improved infrastructure.

In 2002, a quality management system was incorporated into the mass-rearing process, and in 2003 a new genetic sexing strain of Mediterranean fruit fly based on a temperature sensitive lethal (*tsl*) mutation, i.e. the VIENNA 8 strain, was introduced and reared as the main colony (Franz et al. 2021). All these factors significantly improved mass-production levels and quality of the sterile males (Barnes et al. 2015; Barnes 2016).

In 2003 the programme was privatised with the establishment of *SIT Africa (Pty) Ltd*. (Barnes 2007), and in 2004 the sterile male release programme was extended to two additional production areas (Barnes 2016). Financial considerations resulted in the replacement of aerial releases with ground releases in 2003. These were focussed on farm and town gardens and other hotspots where wild Mediterranean fruit fly populations remained high (Barnes 2016). The rationale behind this strategy was to achieve high sterile to wild fly ratios in these localities where wild flies overwinter in low numbers (Barnes 2008), thus minimizing the number of wild flies which are able to migrate back to commercial fruit plantings in summer. However, still insufficient sterile to wild fly ratios during summer often occurred (Manrakhan and Addison 2014).

Subsequently, substantial funds were made available by the fruit industry to introduce extensive fruit fly monitoring programmes in production areas in order to identify and further suppress fruit fly hotspots prior to sterile male releases to ensure that momentum in the SIT programme was maintained. Greater detail on the development, progression and results of the Mediterranean fruit fly SIT programme is given in Barnes (2007, 2016).

When it became clear that a new approach was required to ensure sustainable funding and industry-wide roll out of the Mediterranean fruit fly SIT programme, a 50:50 contractual funding partnership was formed in 2008 between the DFPT and the then National Department of Agriculture (NDA) (now Department of Agriculture, Forestry and Fisheries, DAFF) in the form of a Memorandum of Understanding (MoU).

The broad AW-IPM programme with a SIT component includes, at the time of writing, eight distinct fruit production areas at different levels of SIT implementation. The sterile flies are released in the Elgin, Grabouw and Vyeboom area (9600 ha), the Hex River area (Hex River Valley, De Wet and Brandwacht, 5700 ha), and the Warm Bokkeveld, Wolseley and Tulbagh area (7000 ha), all in the Western Cape Province. Pre-SIT baseline data collection is being carried out in the Hemel and Aarde Valley in the Western Cape (300 ha), the Langkloof Valley in the Eastern Cape (4700 ha), and in the Lower Orange River area in the Northern Cape (Kakamas and Keimoes, 4200 ha).

Fruit fly densities in commercial orchards are monitored with Chempac® bucket traps baited with a three-component lure (Biolure) that are deployed at a density of 1 trap per 20 ha (Barnes 2016). Baiting no longer includes organophosphate insecticides, but the organically certified spinosad-based product GF-120 NF NATURALYTE ™ bait.

The programme contributes towards various government priorities, such as export competitiveness, economic growth and development, job creation, food security, and reduced insecticide use. Monitoring for non-native fruit flies, including *Bactrocera dorsalis* Hendel, which is already established in northern parts of South Africa (Manrakhan et al. 2015), forms part of the national exotic fruit fly surveillance programme, which is augmented through the SIT monitoring programme. For these species, Chempac® bucket traps baited with methyl eugenol lures are used at a density of 1 trap per 100 ha.

3. FINANCIAL MODEL

By 2008, several factors had influenced the economic viability of the programme. These included the absence of sustained investment from government, an inability to raise venture capital from private institutions, a fruit industry which was under economic stress and the resultant difficulties in getting grower buy-in, and a too-small and aging Mediterranean fruit fly mass-rearing facility which could not produce the numbers of sterile flies required (Barnes 2007). It was in this context that the DAFF/DFPT MoU was formalised in 2008.

The DAFF/DFPT MoU is a 3-year renewable contract; in 2009 DAFF's contribution was approximately USD 460 000 (current value) and included an annual consumer price increase. Under the MoU, approximately the same amount was contributed by the fruit industry towards the monitoring and sterile Mediterranean fruit fly production components of the programme. The aerial baiting component of the programme is funded solely by producers.

The objectives of the MoU focussed on the concept that reduced fruit fly population levels can lead to areas of low pest prevalence, pest free areas and, possibly, eradication of invasive fruit flies. This would ensure maintenance of market access and increase South Africa’s ability to export high quality, residue safe fruit. Furthermore, all producers within the relevant area would be able to participate.

Subsequently, the MoU has been renewed twice. The current MoU for the business years 2015/16 to 2017/18 has ensured a financial contribution to the SIT programme by DAFF of USD 770 000, USD 930 000 and USD 1.1 million, respectively.

In 2013 *SIT Africa* evolved into *FruitFly Africa (Pty) Ltd.* (FruitFly Africa 2019), which was recognised by DAFF as the implementation structure for the MoU. DAFF funding is allocated for major projects within the SIT programme, namely awareness and educational programmes, optimisation of fruit fly monitoring, preparation of new areas for sterile Mediterranean fruit fly releases, supplementary fruit fly bait applications, remedial action in hotspot areas, effective radiation sterilisation of pupae, increased production and quality of sterile flies, area-wide release techniques, and continuation of releases in existing areas.

4. ORGANIZATIONAL STRUCTURE

The current (2017) organizational structure of *FruitFly Africa* is given in Fig. 1. During the initial stages of sterile fly production at the Stellenbosch mass-rearing facility, 5 million sterile flies per week were produced by 15 rearing technicians. *FruitFly Africa* currently (2017) has eight rearing technicians; their production output per week has risen from 15 million in 2014 to the 56 million VIENNA 8 sterile males per week in 2017. Production efficiency has been improved not by additional automation, but by the efficient use of labour and the adoption of improved production and quality practices.

A quality control officer monitors the quality of the sterile male flies produced, ensures adherence to the protocol of aerial applications of GF-120 baits, and evaluates all other fruit fly management measures applied in the field.

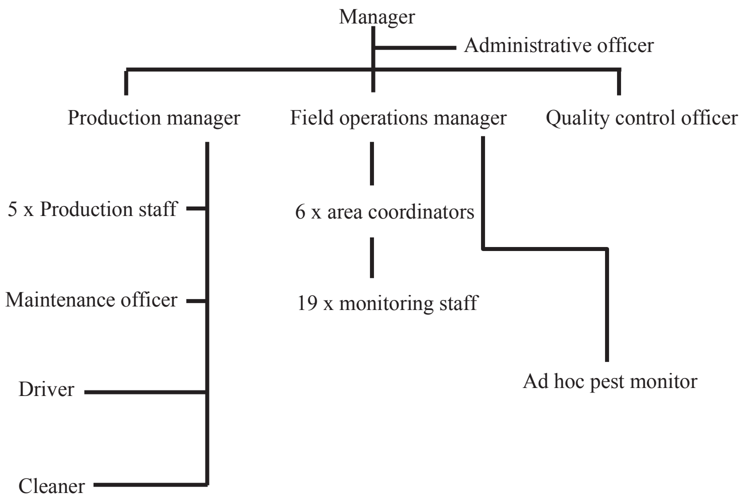

Figure 1: The current organizational structure of FruitFly Africa (Pty) Ltd.

Field surveillance staff carry out the day-to-day tasks in the areas that participate in the programme. Each SIT area has a coordinator who is responsible for planning and public relations in that area. Field monitoring staff report to the area coordinator in that area, who in turn reports to the field operations manager who supervises the implementation of monitoring and management strategies within that area.

5. MANAGEMENT

In a SIT programme, sterile insects must be of the best quality, strategies and decisions need to be technically correct, and customer service has to be excellent. This, coupled with the fact that the broader community which is impacted also needs to contribute to fruit fly suppression, has a unique impact on programme management practices

(Dyck et al. 2021b). As the current programme evolved, it became evident that programme management needs to be able to rely on staff that are technically competent, and that are able to build good working relationships with all fruit industry stakeholders, e.g. community organizations and individual producers. People possessing both these skills are relatively rare, and in this programme much emphasis is put on recruiting suitably-skilled people for these tasks.

Since 2010, area-wide aerial baiting with GF-120 has also formed a crucial part of the fruit fly suppression strategy; in most areas four to six applications per season are applied shortly before harvest as an additional crop protection exercise. Ground-released sterile flies are used as the main intervention in urban areas, farm gardens, on alternate hosts and in Mediterranean fruit fly hotspots.

In view of the encouraging results of aerial sterile fly releases during the 1999-2003 pilot phase in the Hex River Valley (Barnes 2016), and the improved funding base, aerial releases of sterile males were reconsidered and a pilot trial over 2200 ha was implemented during the 2014/15 season using a gyrocopter. Reasonable success was obtained (Barnes 2016), and in 2016/17 season-long, area-wide helicopter releases were carried out at the standard release rate of a 1000 sterile males/ha/week over ±39 000 ha in three areas where the SIT forms part of the fruit fly management strategy. "Attract and kill" bait stations as well as mass-trapping were also used as part of the management strategy in programme areas, although their use has been limited to backyards and hotspots on farms.

Historically, fruit fly monitoring has been at a density of 1 trap per 20 hectares. These traps are not used in orchard-level decision making, but they are used to determine the area-wide distribution of both wild and sterile fruit flies, as well as to determine the ratios between the two. Because all farmers contribute financially in equal amounts to the programme, each of them feels entitled to the same AW-IPM service from *FruitFly Africa* in equal quantities. Once a strategy has been decided on for a season, it needs to be implemented equitably across all participating areas. Fruit fly trap catches have thus been not so much a tool for weekly management decisions, but more as an indication of whether a particular strategy for the season has been successful in that area. They are also a useful tool for timing other control interventions (e.g. host plant management), using historical trends. Trap catches have thus been used to compare fruit fly populations for a whole area across weeks and between seasons. Increasingly, farmers are opting for higher trap densities to enable them to make their own management decisions. For this, more detailed and timely information is necessary, and *FruitFly Africa* is thus developing an electronic database system that will be available to the farmers and provide detailed and real-time reporting on trap catches, and population levels and distribution.

6. PRODUCTION PRACTICES AND QUALITY CONTROL

During the period 2011 to 2015, systematic changes were made to the sterile Mediterranean fruit fly mass-rearing process based on experience gained by the *FruitFly Africa* quality control officer during a visit to the Moscamed El Pino Mediterranean fruit fly facility in Guatemala. These included a 20% reduction in adult fly density in the oviposition cages (from 4400 to 3600 adults – this equates to 0.0027 to 0.0034 cm^3 per fly), twice-daily brushing of eggs off the adult cage screen walls through which the females oviposit into water troughs, and the use of 1 kg 'starter packs' of diet for rearing first instar larvae.

The reduction in the number of adults per oviposition cage reduced the amount of stress on the flies that need to feed, mate and lay their eggs. Brushing the eggs more frequently from the screens through which they have been laid reduced the number of eggs that stuck to the screens and become desiccated, thereby increasing the percentage of viable eggs. The use of the 1 kg starter packs concentrated the recently-hatched larvae in a smaller volume of diet, thereby retaining essential metabolic heat.

Through a cascade effect, these measures resulted in better quality larvae, pupae and adults in the main colony, which in turn equated to better quality eggs, larvae, pupae and adults in the release stream. The end result is the release of better-quality sterile males (Barnes, 2016). The outcome of these changes is given below.

Additionally, a more stable flow of increased funding enabled the production team to make improvements to the facility infrastructure, as well as to the production equipment. This included improved illumination in the adult room, replacing egg-bubbling aeration pumps with a single air supply line, better climate control equipment, and emergency standby services for equipment that is essential to production.

The stable flow of funding also enabled the mass-production facility to procure raw materials of a higher and more uniform quality from reliable sources. Examples of this are bran that is free of pesticide residues, vermiculite with low moisture levels, and yeast with a high and stable protein content.

The quality control parameters and production targets, calculated weekly, include daily egg production (volume), daily pupal production (volume), egg hatch (%), egg to pupa recovery (%), pupal weight (mg), adult flight ability (%), sterility in the release stream (%), and fertility of the main colony (%). All tests are carried out in accordance with the standards set out in the standard operating procedures and in the international product quality control manual (FAO/IAEA/USDA 2019).

7. RESULTS AND DISCUSSION

Following the inception of changes to the infrastructure and mass-rearing procedures described above, there was a marked improvement in the following production and quality control parameters in the release stream (Barnes 2016):

- Daily egg production per cage increased by 45.3%, with a decrease in standard deviation (SD) of 18.2%.
- Mean egg hatch improved from 39.6% to 42.6%, an increase of 7.6% (SD decreased by 50.0%). In 2011 the target of 40% hatch was often not met; this rarely happened in 2015.
- Egg to pupa recovery improved from 16.9% to 20.6%, an increase of 21.9%; there was no change in the SD.
- Mean flight ability increased from 82.2% to 87.5% (SD decreased by 64.8%). In 2011, the target of 80% was not achieved on a number of occasions; in 2015 it never dropped below 81%.

Egg to pupa recovery is a good indicator of the cost-effectiveness of production, since a large percentage of the variable costs of production is spent on rearing the fly from the egg stage to the pupal stage. With an increase in egg to pupa recovery it was not unexpected that the unit cost of production from 2011 to 2015 was reduced by 37% (nominal). In addition to the increased production efficiency, the increase in numbers of sterile males produced, coupled with a minimal increase in fixed costs, translated into lower unit costs, since the increase in total costs were not proportionate to that of total volumes. While the quality of sterile flies together with the cost-effectiveness of production are important to the success of an SIT programme, the effect of the programme on the degree of wild Mediterranean fruit fly population reduction has to be taken into account when considering the cost-effectiveness of such a programme.

The trend in wild Mediterranean fruit fly populations in the sterile male release areas during the period 2007 to 2017 is shown in Figure 2 (note the difference in the flies/trap/day (FTD) scale between the three areas).

The average wild fly population levels during the harvest season (first 20 weeks of the calendar year when ripe fruit is most abundant), in the large areas where the SIT forms part of the management strategy, decreased as follows:

- When comparing the average FTD for 2007-2008 (period before the MoU) with that of 2015-2017, the FTDs in the Hex River Valley decreased by 73% from an average of 4.32 to 1.14. This average includes hotspots that are focally supressed.
- The same comparison for the Elgin/Grabouw area indicates a population reduction of 19% (although the reduction from the 3-year period immediately following the MoU is 32%), from a FTD of 0.50 to 0.41.
- No reliable data prior to 2010 (implementation of the full programme) are available for the Warm Bokkeveld area. When comparing the average FTD for 2010-2011 with that of the period 2015-17, the FTDs in the Warm Bokkeveld decreased by 78% from an average of 1.46 to 0.32.

Over the period 2007-2017 the FTD values for the Hex River Valley were much higher than the FTD values of Elgin/Grabouw. This is mainly due to differences in wild and commercial host plants present and varieties cultivated, as well as harvesting processes and sanitation between the two areas (Barnes 2016), which made fruit fly management throughout the Hex River Valley more difficult. A further factor is climate; long-term data show that the Hex River Valley has higher average maximum temperatures than the Elgin/Grabouw area (Barnes et al. 2015), conditions which favour development of Mediterranean fruit fly (Nyamukondiwa et al. 2013).

Increased funding from DAFF from 2008 to 2017 allowed for essential improvements at the Mediterranean fruit fly mass-rearing facility. The timely integration of a combination of fruit fly management techniques made a positive difference to the outcomes of the programme. Production increased from 15 million sterile male flies per week in 2014 to 56 million per week by 2016, which enabled better sterile male to wild male overflooding ratios. Improved quality and quantity of sterile fruit flies produced and released, better release techniques, and overall, better on-farm management of fruit fly populations, have resulted in a generally steady decrease in average wild Mediterranean fruit fly populations over time, as illustrated in Fig. 2.

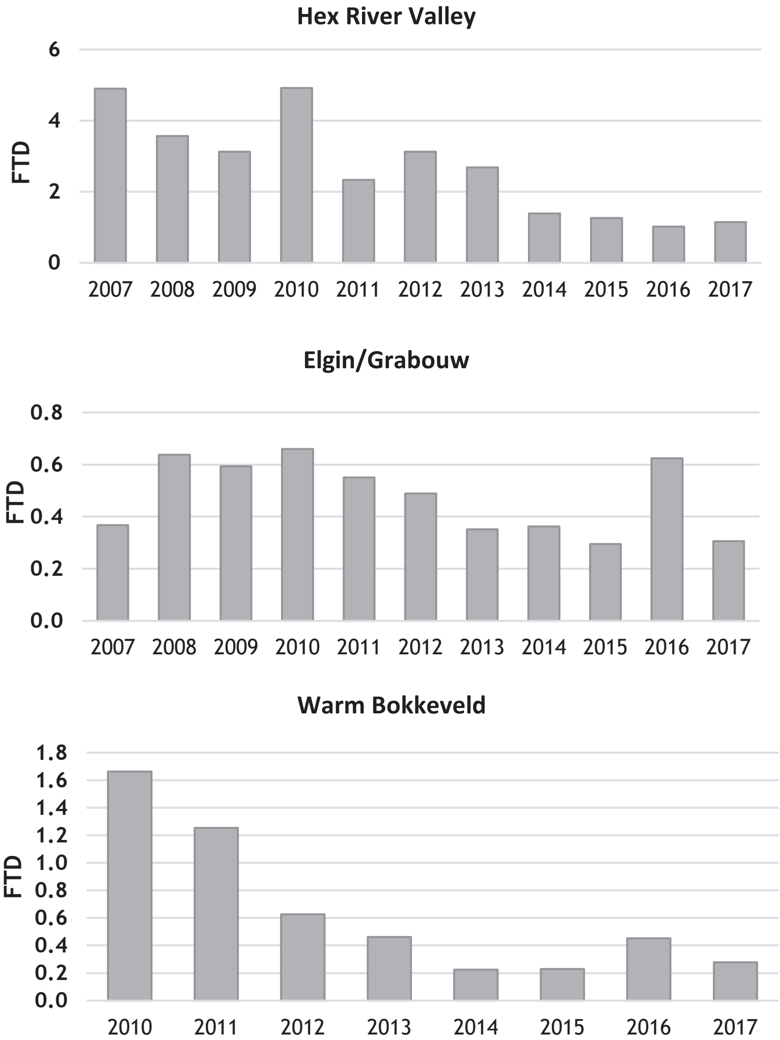

Figure 2. Average numbers of wild Mediterranean fruit flies/trap/day (FTD) trapped in three fruit production areas under SIT application during the first 20 weeks of the year (= harvest period) from 2007/2010 to 2017 (no data available for Warm Bokkeveld before 2010).

During the last 18 years, the South Africa Mediterranean fruit fly SIT programme has faced many challenges such as outdated infrastructure and inadequate equipment due to a poor local funding base, and initially a hesitant grower community, but, with excellent and sustained support from the FAO/IAEA, and later, better co-funding from government, determination by the SIT team, improved facilities and equipment, and a grower community steadily starting to believe in the programme, it has grown to a programme serving a total of 30 000 ha, and is destined for further growth.

Many lessons have been learnt along the way, the most important being:

- Broad-based, multi-organizational and sustainable funding must be available from the start of the AW-IPM programme.
- No single control measure is a stand-alone technology. All available tools for the management of the pest must be used in combination with each other. Efforts must be made to educate stakeholders accordingly.
- The area for the AW-IPM programme, especially at its initiation, must be carefully selected. Besides geographic or topographic isolation, the target pest should already be well managed by conventional methods and sanitation, with growers who are progressive in their pest management outlook.
- Effective management of alternative fruit fly host plants and active orchard/vineyard sanitation at farm level is crucial to the success of an AW-IPM programme.
- There must be buy-in and long-term commitment to the programme by all growers in the selected area(s). Ideally, there should be a 'push-pull' approach by the stakeholders: SIT technologists should 'push' (advocate) AW-IPM (including SIT) where it is appropriate, with a simultaneous 'pull' (a willingness/receptiveness) for the SIT on the part of the growers.
- Good relations and communication between AW-IPM service providers, growers, and the broader public is crucial, and should be based on transparent real-time reporting on trap catches, and population levels and distribution.
- High specification infrastructure, equipment and human capital must be available to produce good quality insects. A good quality management system must be in place in the rearing and release facilities and must include regular internal and external audits of procedures, processes and performance.
- Ground releases of sterile *C. capitata* are not a long-term solution to area-wide population suppression. Above a certain scale, releases should be by air if at all possible.
- Programme managers must keep abreast of the latest international developments in the field of AW-IPM and make good use of knowledge and input from international experts.
- AW-IPM programmes are not quick fixes to a problem. Population reduction exercises can take a couple of seasons to show results. Stakeholder expectations should be managed in this regard.
- Applied research and development should be on-going, and all cost-effective improvements in procedures and processes should be implemented.

South Africa is now aiming to identify some of the existing deciduous fruit and table grape areas in the AW-IPM programme and manage them as areas of low pest prevalence.

The invasion of *B. dorsalis* is officially controlled by DAFF in South Africa and preparedness plans are in place to immediately initiate eradication programmes in case of outbreaks. Official control actions include quarantine, delimiting surveys and eradication measures with the application of the male annihilation technique and bait application (Manrakhan et al. 2012).

Although SIT application for *B. dorsalis* is not envisaged at this stage, future expansion of the fruit production areas to be covered by an AW-IPM approach, which will include the SIT for Mediterranean fruit fly, is planned (Manrakhan 2020). A new MoU with DAFF is planned, which will provide the necessary support for such expansion. This expansion of SIT activities will mainly be within areas where other area-wide control measures (e.g. monitoring and aerial baiting) are already being implemented to effectively suppress populations. Such areas have already been identified in the Northern and Eastern Cape Provinces.

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