The Okanagan-Kootenay Sterile Insect Release Program

Report of an External Review

9-13 June 2014

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CONTENTS

REVIEW TEAM

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Greg Simmons is the coordinator of the California Station in Salinas, CA, with a focus on area-wide integrated pest management programs for agricultural pests. He is experienced in the development and implementation of the sterile insect programme for pink bollworm, and his research areas include control and detection methods and technical analysis of IPM program data, as well as the use of x-ray in sterile insect technology.

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Marc Vreysen is the Head of the Insect Pest Control Laboratory of the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, located in Seibersdorf, Austria. He has more than 25 years of field and laboratory experience with the development and implementation of area-wide integrated pest management programmes in general and the Sterile Insect Technique in particular for plants pest (fruit flies, Lepidoptera), livestock pests (tsetse flies, screwworm flies) and human disease vectors (mosquitoes).

Introduction

The Okanagan-Kootenay Sterile Insect Release (OKSIR) Board requested the support of the Joint Food and Agriculture Organization/International Atomic Energy Agency Division (Joint FAO/IAEA Division) of Nuclear Techniques in Food and Agriculture to conduct an external review of the OKSIR Program in June 2014.

The external review of the program provided an opportunity to consider the effectiveness and efficiency of the OKSIR Program operations. It was an invitation for external perspectives on improving program service. The review measured and reinforced the achievements of this program's area-wide control of codling moth (*Cydia pomonella*). This review thus provided recommendations for the program to meet the changing and future needs of the industry and the community, both economically and environmentally.

The OKSIR Program in British Columbia (BC), Canada, is the longest-running (initiated-1989), most successful, area-wide program for control of codling moth in the world. The program integrates the sterile insect technique (SIT) with orchard sanitation, surveillance, tree banding and mating disruption to greatly reduce the use of insecticides against, and the risk of insecticide resistance developing in, codling moth populations. The codling moth rearing facility in Osoyoos, BC has an annual production capacity of 780 million sterile codling moths. Each year, from April to August, the program uses part of the annual production capacity to treat 3,400 hectares of small orchards intermixed with residential areas in the Okanagan Valley.

The public is increasingly seeking food produced in a clean, safe and sustainable way, free of insect damage. In the last 20 years, the OKSIR Program has been an example to the world of a model that is good for business, good for the environment, and good for the community.

Codling moth is amongst the most economically significant pome crop pests, as it attacks the fruit directly. With codling moth found worldwide throughout all temperate regions, sustainable management of this pest is critical for maintaining viable apple and pear orchards, especially in regions with high pest prevalence. In BC, Canada's western-most province, codling moth had been a serious pest since 1916. Concerns over the extent of codling moth damage, coupled with a desire to significantly reduce the use of chemical insecticides, led fruit growers, scientists and local governments to seek a new approach to codling moth management that was effective, affordable, and environmentally-friendly. They turned to the SIT and mating disruption as the major components of an IPM program.

After more than twenty years of operation, the pome fruit industry and local property owners have drastically reduced populations of codling moth. Through the area-wide OKSIR Program, growers, industry and the local community have significantly reduced fruit damage and the costs associated with control of codling moth. The program has achieved less than 0.2% damage in greater than 90% of all commercial pome fruit acreage, and reduced insecticide use to control codling moth by over 90%. Local industry is using the achievement to pursue an international designation as an "Area of Low Pest Prevalence" and aims to advance relevant market opportunities.

The program is currently evaluating its opportunity to provide better management tools for existing and potential invasive insect species. There is interest internationally to collaborate with OKSIR on piloting and implementing strategies such as the successful OKSIR Program. By sharing leading-edge field practices and successful management and administrative structures with regions affected by codling moth and other invasive species, the program hopes to encourage markets for the sale of excess production of sterile codling moth and/or other bio-control agents produced at the Osoyoos facility.

With its success, the OKSIR Program also faces challenges. Possibly, the main challenge is the trend of declining pome fruit acreage that is causing concern for the long term sustainability of the program. In addition, the reduction in wild codling moth population causes some to view the program as redundant and an unnecessary cost. However, without an area-wide program in place, wild populations of codling moth can easily return to pre-program levels. The program must maintain area-wide management of codling moth in the most cost effective, sustainable manner. Area-wide programming cannot thrive without the support of the public, including key funders, politicians, scientists and community leaders.

In the external review, co-sponsored by the Joint FAO/IAEA Division, the review team conducted interviews with program personnel and key stakeholder representatives, and evaluated program processes and reporting information. The aim of the review was to 1) assess the efficiency and effectiveness of the program's methods used to control codling moth; and 2) advise on the opportunities to improve program operations to achieve the program goals, including potential for diversification of the rearing facility operations and expansion of the scope of the area-wide activities.

This final report will document the findings and recommendations of the external review to the OKSIR Board.

Terms of Reference

The following terms of reference were used for the External Review:

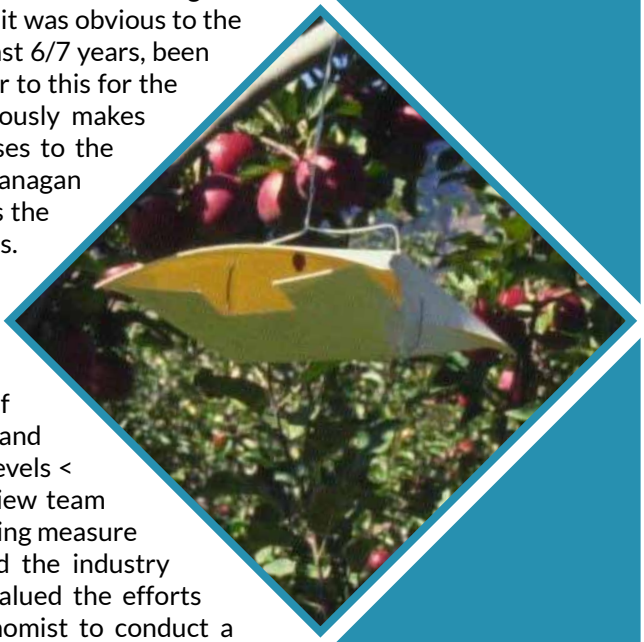
1. Interview program personnel and key stakeholder representatives and collect information about current activities.
2. Use the collected information to address the following critical issues:
    a. Assess whether the Program is using the most effective and efficient method to control codling moth with the resources it has available
    b. Advise on ways to make the Program more effective and efficient
    c. Assess whether the current and planned management and infrastructure are adequate and suggest potential improvements
    d. Advise on potential opportunities to diversify the area wide structure of the Program
    e. Advise on potential opportunities to diversify the operations of the rearing facility
    f. Assess whether the use of SIT can remain affordable with a decreasing wild codling moth population and lessening importance as a key pest in a declining industry
    g. Advise on potential cost effective and efficient alternatives to Gamma Cell technology using Cobalt 60 for sterilizing codling moth
    h. Assess the efficiency of the monitoring component of the field programme i.e. how do we know if we have achieved proper application of controls, either sterile release or pheromone disruption for the level of wild codling moth populations?
    i. Assess the efficiency of the currently used methods of handling, sterilising, transporting and releasing sterile moths and advise on potential improvements.
    j. Assess the efficiency of the public relation efforts of the programme e.g. are there ways for stakeholders to benefit from the achievements of the Program that are not currently being accessed, or how do we convince growers they do not require comfort sprays?
    k. Advise on ways to promote our successful experience and lessons learned in area wide pest management to the benefit of other regions while mutually benefitting the stakeholders of the OKSIR Program?
3. Assess the overall effectiveness of achieving the Program goals
4. Assess the efficiency of the financial and administrative aspects of the Program on achieving the Program goals.
5. Recommend to the OKSIR Board ways to improve effectiveness and efficiency and any necessary changes in Program direction.
6. Write a report documenting the findings and recommendations.

Program Evaluation

A review team composed of six external experts (Des Conlong (South African Sugar Cane Research Institute - South Africa), Gustavo Taret (Argentina), Peter McGhee (Michigan State University - USA), Jim Carpenter (USDA/ARS – USA), Greg Simmons (USDA-APHIS-PPQ – USA) and Marc Vreysen (FAO/IAEA)) reviewed all technical, managerial and strategic aspects of the OKSIR Program from 9-13 June 2014. The review was conducted through interviews and discussions with the OKSIR general manager (GM), project staff, board members, growers and stakeholders of the industry. In addition, the review team was given the opportunity to view field operations and sites, scrutinise project data and visit the codling moth mass-rearing facility in Osoyoos.

Observed Successes

The review team was in general very impressed with the results of 20 years of program implementation. The program is the only one in the world that has been using the SIT as a major component of an AW-IPM programme to successfully suppress codling moth populations below an economic threshold for such a long period of time. The program benefits from a group of passionate, dedicated, and professional staff that has been instrumental to its success. It also can count on the full support of a board that provides the strategic decisions. Like any complex AW-IPM programme, the OKSIR Program has had in the past its share of difficult problems and issues, but it was obvious to the review team that the management of the program has, for the last 6/7 years, been very strong and has resolved some of the issues of concern prior to this for the growers and the industry. The program management continuously makes great efforts to communicate its strategic goals and it successes to the growers, the politicians and the public at large. The entire Okanagan Valley is included in the program and the area-wide approach as the strategy of choice has been instrumental to the program's success. The feedback received during the review indicates that the AW-IPM strategy is well liked by the growers and the industry. The data presented to the review team on the significant reduction of insecticide sales and number of chemical sprays targeting codling moth, coinciding with the drastic reduction of pest pressure (as indicated by the average wild moth captures and on the high percentage (> 90%) of orchards that have damage levels < 0.2%) epitomise the success of the AW-IPM program. The review team considered the reduction of insecticide sales data a very convincing measure of program success, and encouraged the OKSIR Program and the industry to better market this very valuable asset. The review team valued the efforts undertaken by the program management to contract an economist to conduct a benefit-cost analysis that indicated a benefit to the producers from insecticide cost savings, monitoring cost savings and reduction in codling moth injury amounting to CAN $ 395/acre (versus CAN $ 377/acre for mating disruption) because of the AW-IPM program. The data indicated that the economic benefits per acre of orchards are much higher using the OKSIR strategy as compared to using conventional insecticides: this was again convincing evidence of the economic efficiency of the program. The overall benefit-cost ratio of the SIT program was 1.19 for the producer and 2.51 in total (versus 1.35 and 2.37 for mating disruption).



Observed Successes continued

The review team appreciated the importance of the enforcement part of the program and the value and robustness of the funding model that seems to be very stable, with great support of the residential tax payers. The economic survey revealed that a large proportion of the Okanagan population is even willing to increase their contributions to the program. The growers and the industry seem to recognize the good value in the delivery of the OKSIR Program vs. having to provide the same services themselves.

Over the past years, data collection has become completely digitised, which the review team considered as a major positive change. All trap data, as soon as the trap catches are counted in the field, are now entered electronically using GPS linked smartphones with features that allow automatic data transfer to a suitable database that minimises human error. A GIS specialist is permanently on staff and the data is visualised on maps that are made accessible to the growers and the general public. This transparent access to monitoring data is well-liked by the review panel, growers, and the industry.

Since starting operations in 1994, the rearing facility is run extremely well, maintenance and facility operations and hygiene are exceptional. The PPE and "WorkSafe Requirements" are strictly adhered to (personal, radiation) by the facility staff. The facility was very well designed for functionality and for safety of personnel with state of the art equipment that still operates flawlessly. The yearly service to the equipment after the season is bearing fruit. Staff retention is high even with some of the seasonal workers.

The rearing processes are fluid with a well-designed quality assurance/process control program in place. The facility has a very low risk of cross contamination and benefits from an impressive sanitation programme. The facility operates good biosecurity practices that result in an extremely low risk of local infestations around the facility. Although production procedures in the use of a gamma cell are not fail proof in terms of possibility to release fertile moths, the review team appreciated the good checks and double checks in place on the irradiation process. An excellent climate control monitoring system is in place, with an effective alert system in case of problems.

Current levels of irradiation were found to be more than adequate for full sterilization that meets every published standard. The review team considered the produced moths of high biological quality but concerns were expressed with the post factory handling that could reduce moth quality. The location of the facility was found to be appropriate and communication with the public that reside around the facility was found to be good.

The field program is implemented very effectively mainly due to the presence of well-trained field managers who deliver their products well and who showed very good communication skills for outreach activities with the growers. The field equipment was found to be well maintained.

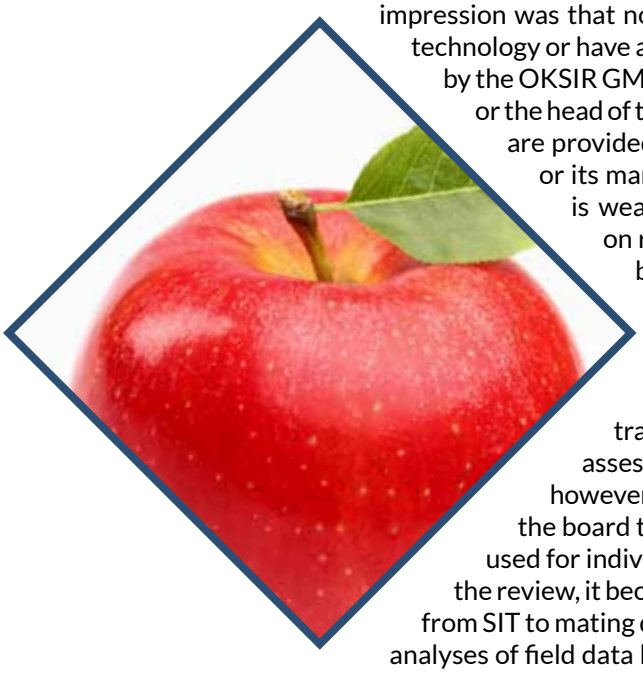
The OKSIR Program has area-wide experience and could be a driver or collaborator in area-wide research locally and internationally. The program has been cooperating with international research groups and has benefitted from some of the research outcomes.

In conclusion, the area-wide program to suppress codling moth using an SIT component has been a great success, with benefits that go far beyond those of the apple producers. The program has in the last decades significantly contributed to making the Okanagan Valley a healthier and less polluted place for the general public. Anecdotal reports on improved biodiversity are testimony to this aspect. The OKSIR Program can in many respects be considered as the standard or a model for other SIT programs, and the project management has in the last year made considerable efforts to raise the profile of the project internationally and to explore possible foreign markets for product delivery. As a result, the expertise available in the program and the rearing facility are recognized and valued internationally as well as by local outside industries.

Program Management and Strategy

The chief governing body of the OKSIR Program is the Board of Directors that makes all key decisions of program implementation, activities, facilities and strategic direction. The eight-member board is composed of five regional district appointees and three grower representatives. The OKSIR administration is headed by a general manager (GM) who is responsible for delivering the program components. The GM of the program reports to the Board of Directors and is assisted by area coordinators, a compliance officer, several field staff, a facility manager and facility rearing staff.

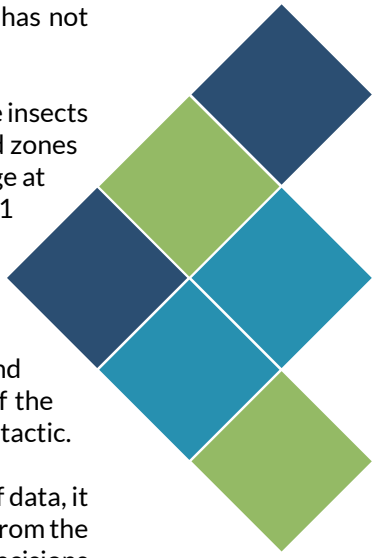
The GM and OKSIR staff have been advised by an Operational Advisory Committee (OAC) that is mainly composed of researchers from Ag-Canada, a government-funded research facility located in Summerland (Okanagan Valley) and grower representatives. In the past years, Mr Hugh Philip (an entomologist) has been hired as a part-time consultant by the OKSIR Program to work with the OAC, which has to an extent improved the scientific advice needed and provided. However, sound input from the OAC on especially technical issues has, in the review committee's opinion, been clearly lacking. The complex demands of operating the program probably require more than an OAC and part-time technical support. It therefore seems that the OKSIR management has often been forced to make many small and large operational decisions on technical issues without any sound technical advice of the current technical support structure (OAC). As a result, changes to program operations are sometimes slow to be realised and many operational features are still being implemented in a similar way as in the proceeding 20 years ("the way we have been doing it since the programme was initiated"). Without strong internal, technical leadership there have been no major technical changes, nor scientific innovative thinking to address some technical issues that could have made the program more effective and more cost efficient. None of the researchers that are part of the OAC are actively doing any research that is related to the SIT, or have any real background or experience with the SIT. The review team's impression was that none of the scientists on the OAC are really interested in the technology or have any firm beliefs that the SIT is a valuable control tactic (Efforts by the OKSIR GM to set up interviews for the review team with the researchers or the head of the institute failed). As a result, the advice and suggestions that are provided by the OAC do not indicate support to the OKSIR Program or its management. The OAC summarily indicates where the program is weak without providing constructive solutions or advice based on results of research. The review team deemed this situation as being far from productive and suggested that urgent changes are required (See Program Staffing section).



The program benefits from a very well implemented monitoring system and data are collected regularly from traps that are deployed in the orchards and from fruit surveys (to assess codling moth damage) at the end of the season. These data however do not seem to be used by the project management and/or the board to make strategic decisions for the overall program but rather used for individual orchard management with staff and the grower. During the review, it became apparent that important strategic choices, e.g. the switch from SIT to mating disruption in zone 2 and 3, are not being made based on sound analyses of field data but are influenced by other forces that sometimes are driven by the special interests of industry, leaders, growers and/or the OAC.

From this, it is clear that the basic concept of IPM, i.e. to use a number of sustainable

management options in a scientific way to best reduce pest insect numbers, has not been followed and is not championed by the advisors.



During the past 20 years, the OKSIR has clearly shown that the release of sterile insects as part of an AW-IPM programme has been very successful, both in zone 1 and zones 2 and 3. This is evidenced by the very low moth catches and the low fruit damage at the end of the season. However, the introduction of mating disruption in 2011 as the major control tool in zone 2 and 3 appeared to have been driven by a prevailing belief that mating disruption would be as efficient as the SIT in the Okanagan and that it would be a cheaper alternative to the SIT. The analysis of the data however indicates that moth catches and fruit damage have increased in zone 2 and 3 since the introduction of mating disruption and dropping of the SIT. This is not surprising, as the very patchy spatial layout of the orchards in zone 2 and 3 reduces the efficacy of mating disruption as a control tactic.

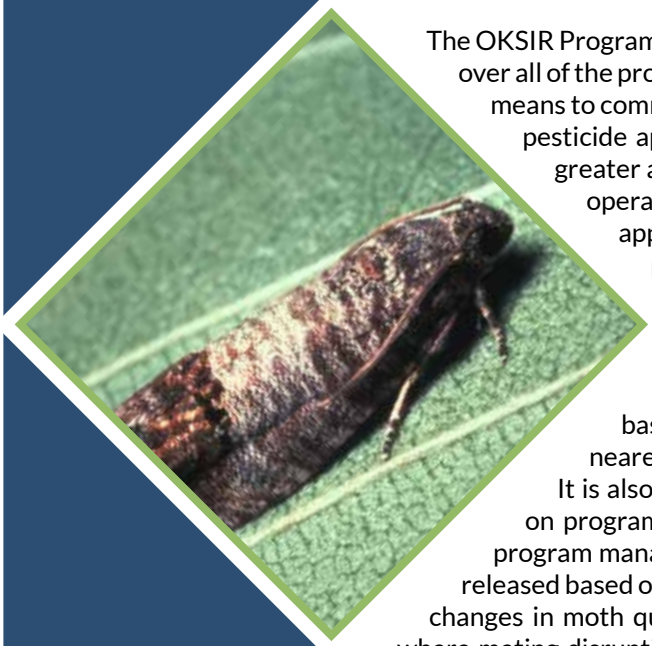
Although enormous efforts are going towards the collection of vast amounts of data, it appeared to the review team that there are no feed-back mechanisms in place from the field/rearing facility to the OKSIR management. Day-to-day management decisions and long term strategies are not based on careful data analysis, but the program is implemented "because that is how it was done before." As an example, the program still uses 40 year old research data to determine adequate sterile:wild moth overflooding ratios (40:1) in the area. Another example: problem orchards are identified through higher catch rates of wild moths or increased damage, but there are no scientific threshold values established that would trigger a certain action such as targeted insecticide application . It is not really clear how a "hot spot" is defined and it seems to be based on trap catches, fruit damage, or a combination of the two. There is however a clear need to establish criteria that allows the development of clear protocols and analysed data feedback mechanisms on which to base strategic decisions for the program. The shift towards mating disruption in zone 2 and 3 entailed that the facility is operating during the season at 1/3 of its capacity, which seems to be a very inefficient use of a key component of the program.

The OKSIR Program is responsible for providing the SIT service to the growers. However, due to changes in the industry and the significant loss of apple/pear acreage, the strategic application is not area-wide anymore. Whereas the SIT is being applied in zone 1 on an area-wide basis, with most growers being very satisfied (some growers commented to the review team that they have not sprayed insecticides for 15 years), mating disruption is applied in zones 2 and 3, with tree banding and SIT in some problem orchards. In the Similkameen Valley , the SIT is being used only in those orchards where a wild moth is trapped, and then sterile moths are subsequently released for 3 years. In the other orchards only monitoring is occurring. Both examples indicate that the approach is not truly area-wide.

Program Operational Decisions

During the review the review team was impressed with the organization, skill and professionalism of the field staff. It was clear that much of the program success is based on the dedication of the staff. However, we found that operational decisions were not unified by a clear central strategy and that increased use of program data such as mapping, insect counts, and spray records could lead to more effective program delivery.

Program operations are separated into three zones and treatments are applied based in part by historical program development and other factors that are not clearly related to the operational needs of the program. We recommend that the program should eliminate the zone designation and manage the delivery of monitoring, sterile release and application of pheromones or other area-wide treatments based on pest pressure. If treatment blocks of apples were organized into smaller neighborhood units based on common agricultural and ecological characteristics, then more uniform program delivery could be achieved based on a clear treatment strategy. This will result in better program delivery and should also help to communicate clearly to growers the program strategy.



The OKSIR Program is using mapping to show wild moth captures and damage levels over all of the program areas. These maps are available online and are an effective means to communicate to growers the status of their fields and can help target pesticide applications if needed. However, the review team believes that greater analytical use of the mapping resource would be helpful to make operational decisions such as where to release more or less moths, apply or reapply pheromone, increase sanitation or make other program decisions. All program treatment operations should be included in the program maps as this a valuable resource for decision making.

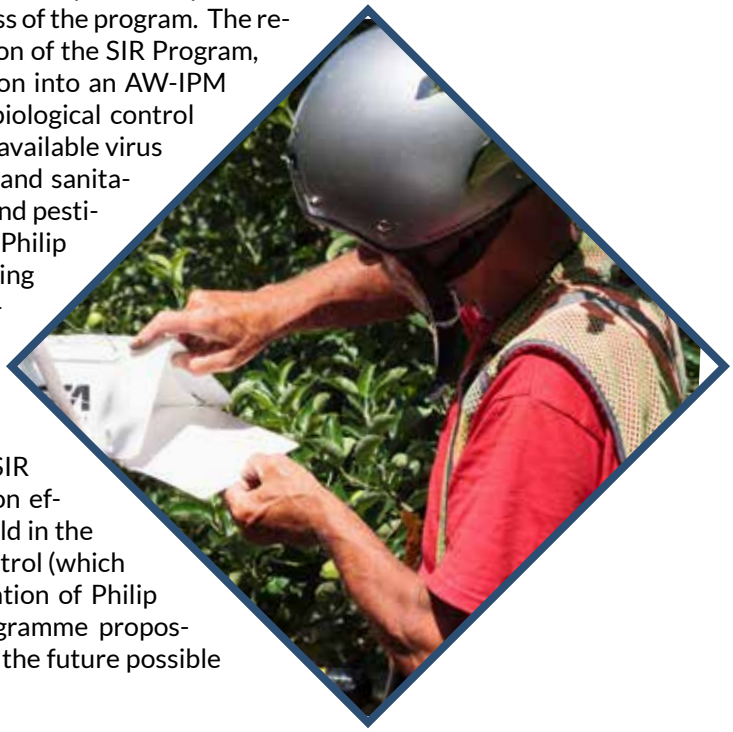
With greater use of mapping analysis, other operational/strategy based decision making could be based on analysis of distance from nearest finds and the effect of block size on treatment effectiveness. It is also common for operational programs to include sterile trap catch on program maps along with wild captures. This information would help program managers to make decisions on where more or less moths should be released based on maintaining over-flooding ratios and can also be used to detect changes in moth quality. Tracking released sterile moth and wild moths in areas where mating disruption is applied can also be used to evaluate the effectiveness of the pheromone application e.g., is the pheromone still effective or are there gaps in the area-wide application?

The program should also continue to attempt to obtain spray records for program tracking and analysis. These would also be helpful to include in GIS mapping, to identify where, when and what pesticide application treatments were made and to analyze in relationship to wild moth capture, damage and landscape and climate factors. Routine collection and analysis of spray records would also be very useful for tracking program effectiveness and cost benefits.

Program Staffing

In January 2013 the OKSIR GM submitted an In Camera memorandum entitled "SIR Staff Succession Planning Process" to the SIR Board for consideration. The contents of this document are fully supported by the review panel.

However, the OKSIR Program has enormous potential to expand and in the light of this, the current lack of applied entomological expertise in key full time positions in the OKSIR Program will seriously limit the effectiveness of the program. The review panel has strongly recommended the continuation of the SIR Program, and the incorporation of the SIT and mating disruption into an AW-IPM strategy against codling moth, expanded to include biological control (e.g. entomopathogenic nematodes and commercially available virus products), along with the current good management and sanitation practices, to continually reduce pest prevalence and pesticide use in the codling moth program (as shown in H. Philip presentation on 2 June 2014 – "Area wide IPM of codling moth and impact on pesticide sales"). Furthermore, because of the threat of new pests in the pome fruit industry, and the increasing crop heterogeneity (especially cherry orchards and vineyards) being experienced in the Okanagan Valley, the management of which recognise the role that the experienced OKSIR Program and staff could bring to their crop protection efforts, it is clear that the role of OKSIR and its staff could in the future be greatly expanded from just codling moth control (which however should remain a major focus). The presentation of Philip and Judd dated 26 February 2009- "Area wide programme proposal"- provides a very good framework on which to base the future possible broader focus of the OKSIR Program.



In the light of the above, it is recommended that the research and extension capacity of the SIR program be increased substantially to bolster the OKSIR efforts. This is prioritised as follows:

Priority 1: An experienced full-time operational entomologist/IPM specialist should be recruited to serve as technical director. This person should have a proven record of leading research collaboration between applied research institutions (such as OKSIR) and universities, government research institutions, industry advisors, growers and be able to direct such research to benefit the OKSIR customers. The incumbent should have experience in identifying research priorities, supervising post-doctoral research associates and post graduate students, as well as junior, middle and senior management staff, to provide advice on the programs operational needs, identifying good pest targets for the program, as well as helping in succession planning. He/she should be at the forefront of promoting the program, its implementation and successes through social media, farmer and local advisor contact (field days especially). The incumbent should work closely with the GM of OKSIR, and the OKSIR governing board, so as to achieve programme goals clearly and in an as efficient a way as possible. It is paramount that this individual has the personality and professional skills to bridge across both institutional and grower communities.

Program Staffing continued

Until this person is in place, and to maintain momentum and progress in the codling moth program, serious consideration should be given to contracting an experienced and qualified entomologist/IPM specialist to lead the programme to provide the appropriate technical advice for the 2015 season, with special attention given to codling moth hot spots and the possibility of combining MD/SIT and other interventions, to increase suppressive pressure in hotspot areas.

Priority 2: A full-time methods development entomologist in the OKSIR rearing facility is necessary, especially if the program is to expand scope and/or scale of rearing operations. Currently the SIR Facility Manager is well supported by the Facility Maintenance Engineer, Power Engineer and Rearing Supervisor to cover the building operation/safety requirements in the facility. However the entomological aspects do not have an expert to provide the advice needed to potentially make the rearing more efficient and cost effective. The methods development entomologist should be a recently graduated PhD student, preferably qualified in entomology crop protection, insect rearing and/or the IPM field, and should be mentored by the Technical Director on entomological aspects of the program, and the Facility Manager on work flow and operational aspects of the insect rearing functions of the facility. The methods development entomologist could be groomed to fill the position of Technical Director, when this post becomes available.

In the light of the above, the program needs succession planning for all key full-time positions. In addition to the two new entomologist positions, succession planning should be available for the SIR GM, Facility Manager, Facility Maintenance Engineer, Power Engineer and Rearing Supervisor. On the field side the Compliance officer, Area co-ordinators and GIS/field supervisor are very important, as they are the programs link with the growers. It is evident that the current compliance officer and area co-ordinators have been in their positions for many years and have built very good relationships with their growers, private industry advisors, and monitoring staff. In the medium term they will be retiring. Good younger senior monitors should be identified to replace the current incumbents, and similarly, good younger monitors should be identified to replace the "promoted" or retired senior monitors. These can be empowered by attending recognised IPM extension courses, training courses in SIT run by IAEA, and in-house training provided by the OKSIR management team.

The continued development of the program depends on good grower relations, and grower knowledge. This can only be provided by an enthusiastic and well qualified extension team. As already indicated, the Compliance Officer, Area co-ordinators and GIS/field supervisor are key in this role. In addition, even though their applied work may be seasonal, the Senior Monitors and monitors are the ones dealing with the growers the most. As such, they need to keep abreast of the latest extension techniques, in order to maintain grower and private Industry Advisor knowledge and confidence in the program. They are the direct link between the program, and the growers/industry advisors in the marketing of the products of the program, so must inspire confidence in these. There are a number of good extension training courses in IPM available, that are run by Universities (See for example the courses offered by University of Florida, *http://ipm.ifas.ufl.edu*, and other websites)

Program Delivery

Communication and Stakeholder Engagement

The success of any good IPM program depends on excellent stakeholder engagement by the program, which leads to full stakeholder support. Stakeholder engagement however is only achieved through good communication at all levels. As such, good communication has to be applied to all levels of engagement of all stakeholder levels, continually and professionally. The field and professional staff directly involved in grower engagement and communication thus need to be dedicated "people persons", who have received the most relevant professional training in extension delivery methods. This makes a professional Program Delivery Strategy as important as a good research base for the acceptance of a good IPM program.

Recent research highlights the importance of a farmer/stakeholder participatory approach to implement knowledge intensive farming practices such as SIT, MD and other control practices in an integrated way (Cockburn, J.J. 2013. Implementation of the push-pull strategy for Eldana saccharina control on sugarcane in KwaZulu-Natal, South Africa. MSc Thesis, Department of Zoology, North West University, Potchefstroom, South Africa. URL: http://hdl.handle.net/10394/9103). Farmers and other stakeholders want to be involved. The older linear type of extension, where a researcher recommends a technology which must be adopted by the farmer/stakeholder to increase crop production (transfer of technology or linear model of innovation (Leeuwis, 2004. Communication for rural innovation: rethinking agricultural extension. Blackwell Science Ltd. Oxford) was suitable for simple input technologies such as implementing improved varieties and agrochemical uses for example, but does not work for the more complex IPM systems (Peshin and Dhawan, 2009. Integrated pest management: dissemination and impact. Springer Science and Business Media. B.V. Dordrecht).

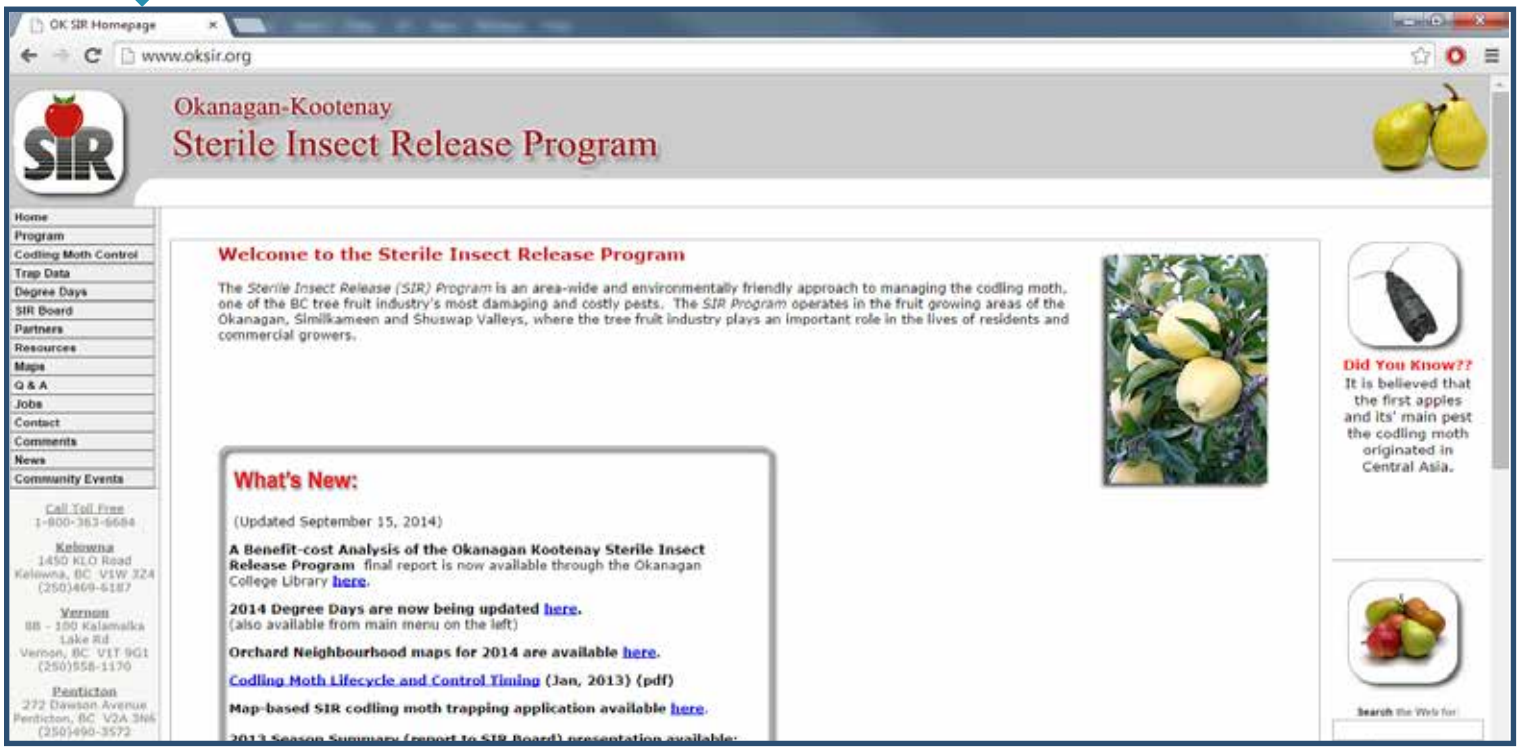
Mixed methods social research is proving to be a good way in which to gauge farmer and stakeholder perceptions and technology adoption/engagement. In many cases stakeholders and farmers have good basic knowledge of their pest complexes and biology and relevant control measures, but lack the more practical knowledge and confidence to implement these more knowledge intensive control measures. In completed studies, the farmers themselves have recommended the use of experiential learning opportunities such as field days and visits to "model" farms (i.e. those farms already implementing the pest control practices) and farmer field schools (FFS), to talk to the farmers already using this technology, in order to get to know more about it and its adoption *(e.g. Meir and Williamson, 2005. Farmer decision making for ecological pest management. In Pretty, J.N. (Ed). The pesticide detox: towards a more sustainable agriculture. Earthscan, London).* For these knowledge intensive techniques to be accepted, it was found that farmers needed suitable learning opportunities (as just described) and good support for intellectual/ apparatus/material inputs.

With the above concepts in mind the following two communication strategies, one publicising the program to the public and influential stakeholder as a whole, and the other aimed directly at the growers/farmers themselves served by the program, need to be developed for the OKSIR program.

Program Delivery continued

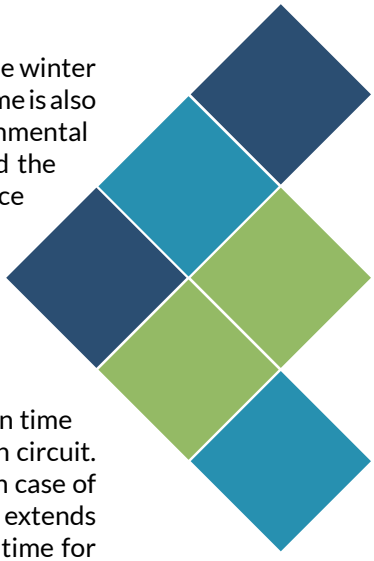
The OKSIR website is good, but must be continually modernised/updated with current information. Ideas in developing a strategic plan should include management taking every opportunity to visit and talk to stakeholders, both technical and non-technical, through radio/TV/press and personal interviews and visits. These could include information stands at town or provincial fairs, arranged field days in areas to showcase recent advances/successes of the program, regular guided visits to the facilities used by the program etc. The use of social media marketing is already a very influential tool, successfully used commercially *(see www.vividengage.co.za – a course offered on social media marketing for your business, covering what is social media, the tools used, history of social media, interesting social media statistics, wrapping heads around social media, the mobile effect, todays customer, who owns social media within the organisation, strategy, blogs, facebook, linkedin, twitter, youtube, etc.)*. Facebook is currently used by the European grapevine moth program for Napa county in the USA to keep growers informed of the advances/breakthroughs in their program *(see https://www.facebook.com/pages/Kick-the-Moth-Out/134909699872159).*

Through mixed methods research one can assess the needs of farmers/growers, and identify what is lacking in their understanding. Set up model farms with progressive growers to address the lack of understanding, and introduce experiential learning opportunities, farmers study groups and FFS's.



Technical Aspects

Rearing Facility



The facility operates every day of the week during the apple season . During the winter months, production levels are kept low and the facility is thoroughly cleaned. Time is also taken for maintenance of all equipment with special emphasis on the environmental control system. The larval diet preparation equipment, seeding machine and the larval trays washing machine are likewise included in the annual maintenance plan.

The facility has seven permanent staff that work year round. During the apple growing season, temporary personnel are recruited to be able to scale up production.

The facility is kept in excellent working condition, with air filtering changed on time ensuring no physical damage to insects due to air imbalances in the collection circuit. The facility however lacks a back-up generator which should be considered in case of a power failure. Although the time required for the maintenance of the facility extends throughout the offseason, it could be completed in one month giving ample time for off season production to provide codling moths (or other insects) to other national or international customers.

Equipment that is used for larval diet preparation is in very good condition. The protocol for the preparation of the diet is clear, and the sequence and timing of mixing the different raw materials is routinely established. Each week, 40 kettles of diet are prepared (totalling 8.72 tons of diet produced per week) which is required to produce approximately five million codling moths per week. This results in a recovery index of 0.57 million codling moth/ton of diet. The raw materials used for the larvae diet are prepared and weighted on the first floor and funneled into the mixer which is located on the ground floor. Diet mixing occurs with a minimal amount of handling by the facility workers. The mixers are made of stainless steel which gives minimal contamination and can be easily cleaned. The movement of the diet through the machine assures adequate asepsis of the diet. Thereafter, a custom designed machine distributes specific quantities of diet in the larval trays. Production report from 2013 showed that an average of 4.1 million moths were released per week.

The oviposition paper that contains the eggs is divided into pieces of adequate size and deposited on the trays with the larval diet.

The oviposition cages in the oviposition room were all in very good working condition. The cages are rotated automatically to facilitate homogenous oviposition of the eggs on the surface of paper. The egg sheets are treated with bleach and water solution to prevent any potential contamination before they are place on the seeding trays. Trays are placed in mobile racks that can be transported to the larval development rooms.

The larvae are kept in larval development rooms until emergence from the pupae. Each seeding date goes to a specific larvae development room. Temperature in the rooms is increased with advancing larval period which slowly will dry out the diet. It also induces the larvae to pupate within the diet. Backup rooms are available to allow proper cleaning of the rooms and adequate sanitation.

Technical Aspects continued

The racks with the trays that contain pupae that are close to emergence are shifted to emergence rooms. Trays of each seeding date are maintained for three days in the emergence room to provide ample time for the pupae to emerge. Adult moths are attracted to UV lights in the dark room that are switched on/off with regular frequency. Moths that reach the UV light are sucked up into a ducting system that brings the moths to a cold room where they are collected in containers and immobilized for irradiation.

Immobilized moths are put into petri dishes at a density of 800 moths per dish, and put in a rack system that fits into the Gamma cell 220.

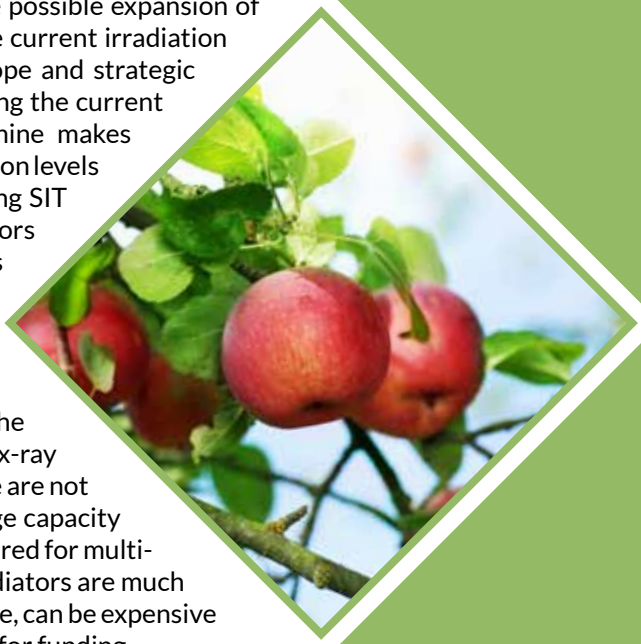
The facility has a well-equipped quality control section. The following parameters are reviewed on a continuous basis: egg counts per sheet, egg hatch, adult emergence, pupal and adults weights. Parameters such as flight ability and survival are not determined. Also QC parameters in the field are not determined. The review team suggested that QC control procedures be introduced in the field and during different steps of the process (pre irradiation, post irradiation, post shipment, pre releasing, post releasing). Compatibility and competitiveness tests would need to be carried out at least once a year. It is recommended to establish threshold values for the various QC parameters for ease of analysis of the data.

The location of the facility was discussed and the review team considered the location as very adequate.

Radiation Source

The program irradiator is a MDS Nordion GC 220 purchased as a refurbished unit in February 2001. At the time of purchase it had a charge of 23,811 Ci or 881 TBq (60Co) and it has not been refreshed since 2001. The irradiation chamber of the Nordion GC 220 can accommodate a stack of 12 Petri dishes, with each Petri dish containing 23 grams of chilled codling moths (~800 moths). Currently, the irradiator requires 228 seconds to irradiate to an absorbed dose of 200 Gy. Therefore, 228 seconds are required to irradiate 12 Petri dishes (~9,600 moths). Additional time is required to load and unload the irradiator, and to verify that all safeguards are in place and observed.

The 2014 program requirements are 4372 Petri dishes/week for 18 weeks. Program management has calculated that by operating the irradiator 24h/day it would theoretically be possible to irradiate 24,192 Petri dishes/week in 2014. Due to the radioactive decay of the 60Co in the irradiator, it is calculated that maximum throughput (24h/day) would decline to 21,924 Petri dishes in 2015, 19,509 Petri dishes in 2016, and 17,528 Petri dishes in 2017. However, it is strongly recommended that operating the irradiator 24h/day for 18+ weeks should be avoided because of the stress it would place on the mechanics of the device.



Considering the declining throughput of the irradiator and the possible expansion of irradiator use, it is recommended that the program replace the current irradiation source within a timeframe that accommodates the future scope and strategic direction of the program (2-5 years). Refurbishing or recharging the current machine is not recommended because the age of the machine makes mechanical failure probable. Irradiation time at current production levels will nearly double within the next five years. Almost all ongoing SIT programs in the world use 60Co irradiators. A few 137Cs irradiators are still in use, but the expense and/or unavailability of 137Cs will most likely limit the use of this isotope for SIT programs in the future. The IAEA has partnered with industry in the development and evaluation of x-ray technology for SIT programs. After several years of collaboration and the installation of x-ray irradiators at some SIT programs, the evidence is overwhelming that, at this time, replacement with x-ray technology is not recommended because the machines available are not reliable enough for an operational mass-rearing program. Large capacity irradiators such as panoramic or electron beam could be considered for multi-functional use, including codling moth SIT. However, these irradiators are much more expensive to purchase and install, require much more space, can be expensive to operate, and rely on sustainability of the multifunctional use for funding.

We recommend that the Program initiate the sourcing of a new self-shielded 60Co irradiator, similar to the current Nordion GC 220, with the goal of making a purchase within 2-3 years.

Technical Aspects continued

Safety and Security

We observed that the program operation and management of sterile moths is sound and secure. Staff is well trained and follow procedures. The use of colorimetric radiation exposure tags (RadTag) is routine. We noted that in late 2013, preventative maintenance and inspection of the machine was performed and no safety, age or operation problems of the GC 220 irradiator were identified. Also in 2013, inspectors from the Canadian Nuclear Safety Commission performed an annual safety audit and review of equipment and operational use and no deficiencies or safety issues were identified.

The review team did notice that if improvements were made in moth handling/ irradiation packaging procedures and lay-out of the moth irradiation area that this would increase biosecurity and further reduce risk of an already low risk operation. The following changes to the collection and irradiation procedures are advised:

1. Current practice is to reuse the plastic petri dishes used for moth irradiation and transport for release into the field. These dishes were observed with the old RadTags still on the dish covers. The old RadTags should be removed from the Petri dishes before reuse or new Petri dishes should be used. Although staff is well trained, the use of an old RadTag could be a source of confusion.

2. The irradiator is housed in the same room where the moths are collected and unirradiated moths are stored in the same area as irradiated moths. While these are kept in separate containers and spatially separated within the room, it is a standard practice in most facilities to store irradiated and unirradiated moths in physically separate and isolated areas. A possible solution is to construct a wall between the irradiation and collection room with a pass-thru window so that a one-way direction process of fertile moth collection to irradiation area and irradiated moth storage can be established.

Transport and Release

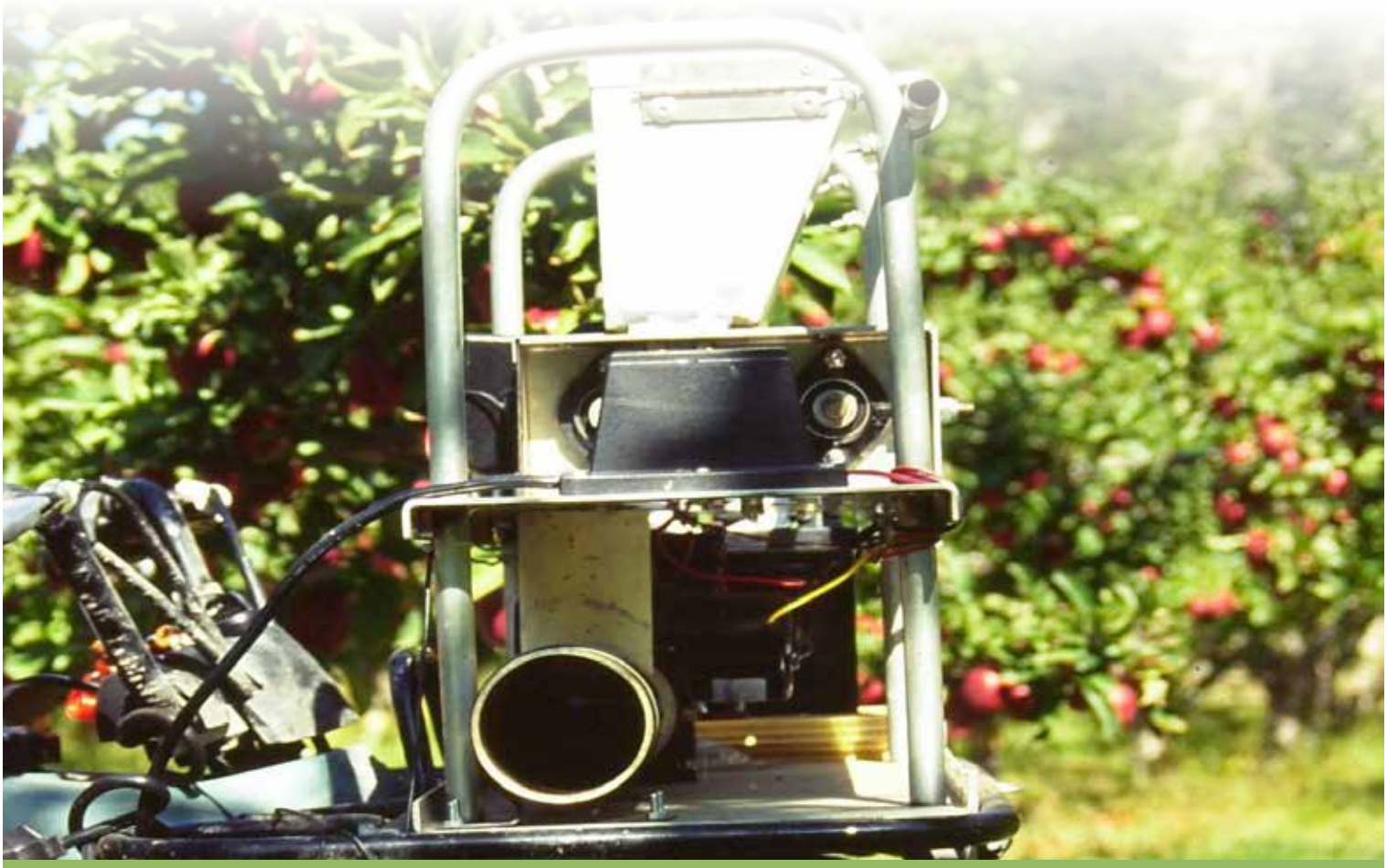
A major factor in the success of the SIR Program has been the ability to consistently deliver and release quality sterile moths into the target orchards in a timely manner. Moths collected from the insectary emergence rooms by wind traps are transported in an air stream within flexible tubing and chilled when deposited in the cold room. Moths remain in a chilled and immobile state during the packaging and irradiation, and the cold-chain is maintained during transport to the orchards and until release. Moths are released in the orchards from all-terrain vehicles (ATV). An insulated cooler box for holding chilled moths is mounted on the back of the ATV and a moth release device is mounted on the front of the ATV. The ATV driver removes a portion of the chilled moths and places them in a funnel canister on the top of the release device. Chilled moths are gravity-fed into a tube where an air stream created by an electric blower gently ejects the moths horizontally onto the orchard floor beneath the fruit trees as the ATV travels through the orchard. Depending on the ambient temperature, the temperature of the cooler box, and the length of time the moths have been in the release device, some moths may fly when ejected from the release device, while other moths may remain on the ground until they have warmed enough to initiate flight.

The successful transportation and release technology used by the SIR Program still has some inherent elements that should be examined for potential opportunities to optimize program efficacy and cost/benefit. Ground release using ATVs has many possible positive attributes: operational in almost all weather conditions, targeted releases in small patchy orchard blocks, low-tech with liability of mechanical failure distributed across the fleet, "on-farm" presence of program weekly/semi-weekly, and operator observations of moths at the point of release in the orchards. However, most SIT programs use some type of aerial release technology. It is therefore suggested that the SIR Program consider evaluating the merits of aerial releases and conducting trials comparing the cost of delivery and the quality/performance of released moths for the current ground release with aerial release. The SIR Program may wish to contact the IAEA for technical assistance/advice in setting up field trials on efficacy and moth quality through aerial releases. Another potential partner in making these evaluations might be the Pink Bollworm Eradication Program in Phoenix, AZ. Because the pink bollworm eradication is almost complete, no sterile moths are being released this year. It might be possible that one of the release planes would be available to participate in a trial.

Technical Aspects continued

Specific modifications to the current ground release technology and procedures also may optimize program efficacy. Studies have shown that vibration (especially over time) can reduce the quality of insects, and that performance of irradiated moths is reduced when cold moths are released on cold ground. Procedures used by the false codling moth program (XSIT) in South Africa include permitting the moths to warm slightly before release from the ATV-mounted release device. This allows the moths to be ready for flight at the time of release. Also, the XSIT program ATV release device directs the released moths upward into the tree canopy. The SIR Program should evaluate modifications to the moth handling procedures and the ATV moth release device that may improve the quality and performance of released moths. These modifications could include a release cylinder oriented upward towards canopy rather than horizontally, warming moths in canister system before release, use of a warm-up compartment before release, and use of vibration dampening materials in the transport containers.

It should be noted that some of the equipment (ATVs, cooler boxes) are showing wear and need to be replaced in order to maintain continued on-time delivery of high-quality insects. Further, equipment that appears to be compromised in its function may detract from the SIR Program's effort to portray a positive image to growers, stakeholders and the public.



Program Monitoring

The OKSIR Program currently employs a monitoring plan utilizing a number of strategies to assess wild populations in SIT and MD treated orchards. Pheromone baited traps (Trécé L2 or 1mg) are deployed in SIT regions to assess wild populations in orchards as well as providing feedback on responsiveness of SIT males. Traps baited with CM/DA combo lures (3mg codlemone + pear ester) have recently been incorporated in MD orchards along with traps baited only with pheromone lures. In both management strategies the total trap density is ca. 1 trap per 1-2ha.

Seasonal inspection of fruit occurs in all orchards prior to harvest in order to detect larval injury. Depending on the size of orchard, end of season harvest sample selects 500 to 1000 fruit for visual inspection on the tree for frass or oviposition damage. Harvest sampling procedures have been reduced in the last few years because of staff shortages. Banding trees with corrugated cardboard to capture overwintering codling moth larvae is also employed. Trunks and major scaffolds are banded in May/June and collected after harvest. The number of larvae detected is recorded for each orchard. These direct pest density assessments are particularly labor intensive as many field staff leave prior to sampling as they return to university studies in late summer.

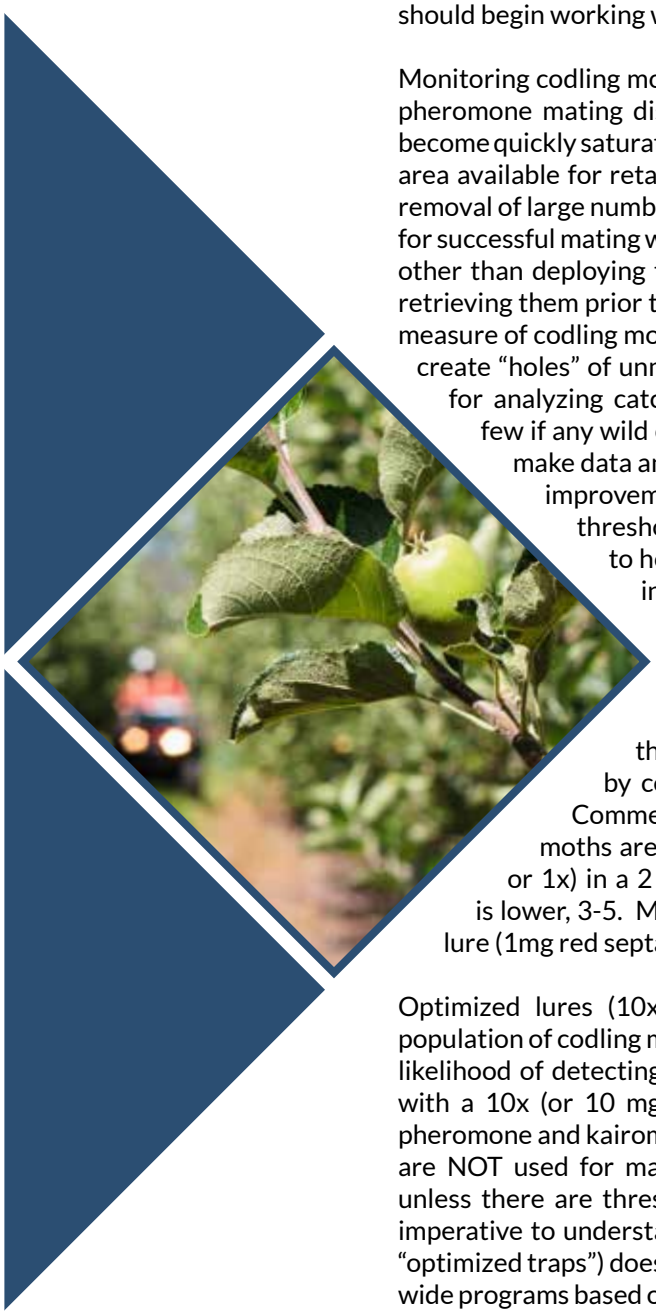
Previous efforts included surveying buffer zones surrounding SIT orchards for feral host trees, and removal and replacement of residential pome fruit trees with a none-host plant through a credit voucher system. The credit voucher program was highly successful at reducing host plants, but was discontinued due to the high cost.

Current target thresholds for the SIT program aim for less than 0.2% fruit damage at harvest and zero codling moth captured in traps. Releases of sterile codling moth are scheduled 1-2x weekly based on wild codling moth pressure until achieving zero wild moths captured for 3 seasons. Orchards without codling moth catch for 1 season cease to get SIT releases but monitoring with traps, cardboard bands, and fruit assessments continue. Upon catch of a single wild moth SIT releases are reinstituted and continue for a minimum of 3 years.

These survey efforts are very labor intensive, but through the passion and dedication of the OKSIR field staff, have resulted in a very successful codling moth management program. OKSIR utilizes an internal data management program for all assessment data. Moth captures are entered into a database at each trap visit onsite and are accessible to growers and crop consultants online and via email. This data system is robust and ahead of many private and industry crop consultants. Feedback from industry representatives (growers and crop consultants) indicates the monitoring program is highly valued and paramount to the success of the AW program and that they want this to continue into the future. The strategies in place have provided a solid foundation for assessing wild codling moth populations and responsiveness of codling moth SIT.

Technical Aspects continued

The OKSIR Program should continue to employ an ongoing robust, sampling plan that combines pre-harvest damage data, trap data, and band data, with two objectives: 1) evaluate overall program efficacy, with consideration of existing data set to ensure some degree of continuity, 2) make operational decisions. Recommendations to enhance the overall monitoring efforts and further reduce codling moth presence in orchards follow. It is imperative to obtain fruit injury and chemical spray records from packing sheds to evaluate the success of SIT and MD management strategies. The OKSIR staff should begin working with local packing shed management to obtain these data.



Monitoring codling moths in area-wide pest management programs including SIT and pheromone mating disruption is uniquely challenging. Traps in SIT orchards often become quickly saturated with sterile codling moth males resulting in less sticky surface area available for retaining wild moths that are the primary target. Additionally, the removal of large numbers of SIT males reduces the overall competition with wild males for successful mating with wild females. There are few options to alleviate SIT captures other than deploying traps (or sticky liners) several days following each release and retrieving them prior to the next release. The current density of traps provides a good measure of codling moth densities and a reduction in the number of traps would likely create "holes" of unmonitored regions within the orchard. There is however, room for analyzing catch over several years and removing traps that have captured few if any wild codling moth. Altering the type of trap or lure employed would make data analyses from year to year more challenging. The most significant improvements in monitoring with traps is to reassess management thresholds, deploy additional traps along orchard perimeters adjacent to host habitats or areas with a known history of pest pressure, and increase monitoring in buffer zones to improve the degree of confidence in making management decisions.

Understanding trap thresholds is paramount to optimize management decisions especially in MD orchards. Management thresholds in commercial apple orchards should be obtained by consulting with pest control advisors in the Pacific Northwest. Commercial growers in Michigan do not apply insecticides until 5-7 moths are captured in a single trap baited with a standard lure (Trece L2 or 1x) in a 2 week period; in pheromone disrupted orchards this threshold is lower, 3-5. Management thresholds are based on the standard codling moth lure (1mg red septa, 3mg long life or grey septa, Trece Inc).

Optimized lures (10x or CM/DA) are used to estimate the overall background population of codling moth (relative density) in MD treated orchards or to increase the likelihood of detecting codling moth when pest densities are very low. Traps baited with a 10x (or 10 mg codlemone) lure or a combination lure (CM/DA) containing pheromone and kairomones are used ONLY to assess the presence of CM. These lures are NOT used for making management decisions regarding insecticide application unless there are thresholds established specifically for this lure and purpose. It is imperative to understand the presence of a pest at low densities (especially in these "optimized traps") does not necessarily mandate insecticide sprays. Codling moth area-wide programs based on SIT and MD decreases the probability of males finding females thereby reducing mating. Growers should realize less codling moth pressure over time and therefore a reduction in the number of targeted insecticide sprays without increasing injury to the crop.

Seasonal codling moth catch from orchards, banding data, and fruit injury should be used to assess which regions are most likely at risk from wild females. Employing baited traps in buffer zones surrounding SIT and MD orchard regions can provide an easy assessment of areas at greatest risk. Codling moth is a rather sedentary species *(Mani and Wildbolz, 1977. The dispersal of male codling moths (Laspeyresia pomonella L.) in the Upper Rhine Valley. Zeitschrift für Angewandte Entomologie, 83: 161–168)* and the majority of moths disperse less than 800 m *(Thistlewood, H., Judd, G., Clodius, M., 2004. Development of methods for sustainable management and monitoring of codling moth, final report to the Okanagan-Kootenay Sterile Insect Release Board)*; a minority of adults disperse longer distances (up to 8 km). Extending the buffer survey zone outward to 200-500 m would likely decrease the chance of female moths flying into commercial orchards. Deploying traps baited with combination lures (CM/DA) in buffer zones would increase the probability of detecting wild male and female moths moving into commercial orchards. Traps baited with CM/DA lures preferentially capture mated vs. unmated females and would be a better choice than pheromone only lures. Areas near orchards sustaining codling moth injury or historically catching consistent or high numbers of codling moth should increase buffer zone trapping and visual surveys for backyard host trees. Site inspection of problem orchards for poor sanitation and or management practices should coincide with buffer zone monitoring.

Technical Aspects continued

Quality Control

The SIR Program rearing facility conducts weekly quality control (QC) and process control tests. These tests include larval diet pH, % females mated in facility, sex ratio of emerging adults, adult weights, moth collection sample observed for physical condition, pupal group weight, exuvia (emerged adult moth) counts per tray by batch, larval mortality, egg count per egg sheet, and percent egg hatch. Monthly air quality tests are performed in key areas used in the facility. Other tests performed throughout the year are irradiated and non-irradiated moth longevity trials and confirmation of sterility at various absorbed dosages.

Currently, no monitoring is being employed to assess the "process control" of transportation and release of irradiated moths, and to assess the quality and performance of irradiated moths released in the orchards. It is recommended that the SIR Program implement field quality control protocols to assess 1) cold-chain temperatures throughout the moth delivery process and 2) quality and performance of insects at arrival to the release site. The SIR Program has some experience in conducting a flight test that has recently been reported to be useful in monitoring moth quality. Periodic use of this flight bioassay could be useful in comparing moth quality at various points throughout the handling process (i.e. after emergence and collection, after irradiation, after transport to the orchards, and after transport in the ATV). Comparisons could also be made of moth quality for moths delivered and released in different geographical areas, or during different seasons. Although the SIR Program collects % recapture data from pheromone-baited traps to determine the sterile:wild overflooding ratio, this data should be augmented by a flight bioassay to measure moth quality, because the rate of recapture is highly variable and strongly influenced by meteorological and physical conditions within the orchard. It also is recommended that the SIR Program develop quality control protocols for confirming quality of moths during export processes and for establishing export quality standards. Flight bioassays also may be useful in developing these standards to assure customers that they are receiving a reliably high-quality product.

Future Program Directions

The review panel is impressed with the overall organization, management and program delivery by the OKSIR program. The rearing operations are well run and the facilities are kept in excellent condition. The field and rearing staff are well trained and motivated to deliver a high quality codling moth program. Because of declining apple acreage there are concerns about the long-term sustainability of the program and options for diversification or expansion are under consideration. The review panel agrees that to ensure long-term sustainability of the program, the program should evaluate possible expansions of scope and/or scale to diversify and supplement revenue streams. The review team thinks it is important to note that pursuing any of these strategies would require additional in-house scientific technical/methods development support as well as the possible need to seek outside expertise.

There are two basic approaches that are on the table: 1) expansion of the scale of current activities by increasing the production of sterile moths and/or delivery of field services against codling moth, and, 2) expansion of the scope of current activities to target other agricultural pests.

Expansion of Scale

The program should continue to explore possible options for export of sterile codling moths to other apple growing regions. The most favorable option would be to sell moths during the off-season to a southern hemisphere country. This would allow year round operation of the rearing facility and would not interfere with the supply during the season in the Okanagan region.

Another option would be to try and expand the market into Washington state, California or other areas in the US or Canada having difficulty with codling moth. Given that most other apple growing regions use area-wide application of pheromones, this may be difficult but as pheromones typically only reduce moth catch by ca 80-90% there may be opportunities to provide service in this market. The combined use of SIT and pheromone can be very effective, especially when treating area-wide on isolated blocks. Many of the apple production areas in Washington State are surrounded by desert/arid lands and these would be good targets for SIT. However, careful consideration by the SIR Board should be given to the perception that Okanagan property owners may have their tax dollars subsidising the pome fruit producers in outside areas, especially production areas that are in direct competition with their growers and industry.

The program has some business with codling moth pheromone researchers in the U.S. This is pretty small but it may be possible to expand this market to provide codling moth (as eggs or larvae) to research labs involved with pesticide development or resistance monitoring. There are some companies that provide similar services and this may be an area that could be developed (e.g. Benzon Research (www.benzonresearch.com).

A complimentary expansion of scale could be to also offer the area-wide codling moth management service along with sterile release, monitoring, GIS mapping, sanitation and treatment guidance, in effect, selling the same service that the program currently offers to growers in the Okanagan region. This would seem to be most practical for apple growing areas in Washington just over the border.

Expansion of Scale continued

Program personnel could travel to provide the service, though in more distant locations the program could contract with an entomologist to provide the service and make releases, assuming the new program area is large enough to sustain remote employees.

In any scenario of selling moths to other regions, a full time dedicated methods development entomologist should be contracted to develop and test shipping methods, enhance handling procedures and develop other needed technology to ensure constant high quality of shipped moths (See staffing section). It is unlikely that, except for shipments to North America, delivery of moths to distant locations will reach their destination in less than 2 days, with 3 days more likely. Although there has been work that shows 72 day old moths can be high quality, it will still be difficult to achieve high quality moths in shipping, and the shorter time in transit the better. Faster shipping, such as contracted air freight may be cost prohibitive. A target of 3 days or less in transit for shipments of moths will likely be the needed goal. Current operational sterile moth release programs rely on overnight shipments with releases occurring the next day in their operations.

If it appears that there is a real possibility of developing a foreign market in Europe or the Southern Hemisphere, a useful development would be to devise methods to collect and irradiate pupae so that sterile moths could be shipped as pupae which would result in an increase in moth quality. This would not be a trivial change as, except for sterile fly programs, there are no operational moth programs that irradiate pupae.

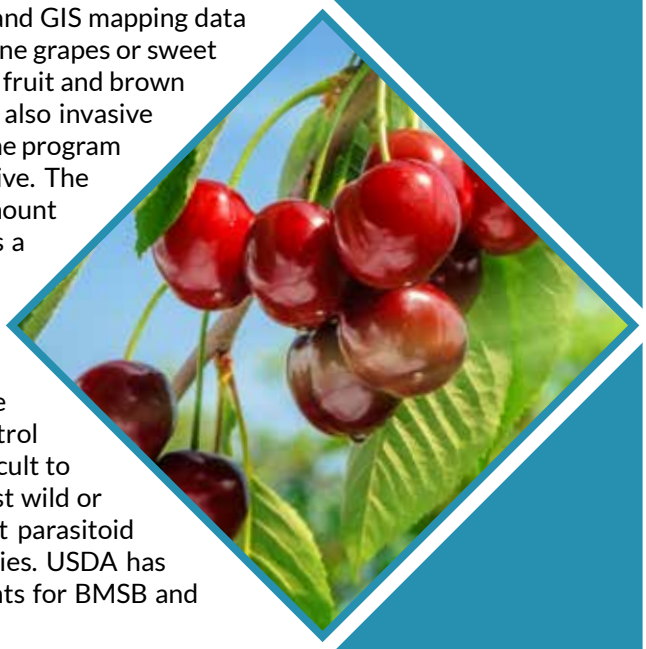
The problem with irradiating moth pupae is that there is a wide variation in pupation time and developmental stage for moths resulting in collections of pupae of different ages. Moth pupae that are irradiated before they are fully developed have lower emergence rates and are of poorer quality. The other difficulty is that in the codling moth system, moths pupate in the diet which makes collection of pupae difficult.

Still, the benefits of running a moth release program requiring greater than 1 day in transport may be worth an investment to develop a pupae collection and irradiation system. There may be ways to manipulate the diet, or develop a pupal separation or washing method to collect pupae (e.g., wash diet trays in 1-2% NaOH solution to dissolve silk and separate diet). There may also be larval rearing methods that can be developed that can result in collections of more even-aged pupae. Last, it should be possible to artificially select or breed a strain that has faster and more uniform pupation time.

We note that the largest operational sterile release moth program, pink bollworm (PBW), has recently started to investigate pupal irradiation methods. This is because of the successful eradication program in the SW United States. Here sterile releases have been suspended and will only be restarted in the event of an outbreak. For reasons of biosecurity, the PBW facility is now only rearing to the pupal stage as manipulation of only this stage would mean far fewer adults in the facility that could escape.

Expansion of Scope

The idea of expanding the range of services, or providing different sterile insect species or even biocontrol agents were discussed with the review team. The review team believes that one of the most promising avenues would be to expand program services to groups of other fruit growers in the region. The technically simplest options would involve offering area-wide monitoring, treatment coordination and GIS mapping data analysis to another one of the major crops in the area, such as wine grapes or sweet cherries. Pests such as spotted wing drosophila, western cherry fruit and brown marmorated stink bugs (BMSB) are current threats. There are also invasive pests that could arrive and any time and there may be value for the program to offer monitoring service for high risk pests that have yet to arrive. The recent experience of the California grape industry having to mount an eradication program against the European grapevine moth is a case in point. Early detection and emergency response is key to elimination of a new pest before it can become widely established.



For invasive pests that have already become established, the program may consider the production of exotic biological control agents. Pests such as BMSB, with a wide host range may be difficult to control across the landscape. In addition, their potential to infest wild or urban hosts may make the production and release of specialist parasitoid wasps a good tactic to help reduce the pest risk of these species. USDA has sponsored foreign exploration for new classical biocontrol agents for BMSB and these may soon become available release.

The review team also understood that there are some proposals to produce entomopathogenic viruses for codling moth or other pest species. The idea is that the moth production facility could provide a steady supply of hosts especially during the winter months for virus production. There may be possibilities here, but this is a highly technical arena that is highly regulated. If there is a market we expect that the best options would be to partner with a company that would take on the responsibility of safety testing, registration, labelling, marketing etc. Other possible products could include entomopathogenic fungi or nematodes.

Last, there may be possibilities to produce another sterile insect species either for pest control in Okanagan/Canada or for shipment to foreign markets. In this scenario, the OKSIR rearing facility could produce diet, rear the insects, provide irradiation and ship. Depending on the species and the need for space for codling moth production within the facility, there may be room for production within the facility. However, rearing requirements for other species may be incompatible with codling moth production and there may also be a risk of contamination of the codling moth rearing or other risks to the codling moth production.

Expansion of Scope continued

An option that would reduce the risk to the codling moth colony and expand the space for rearing another species would be to develop modular building rearing systems that could be placed outside of the facility. Additional rearing space using shipping containers (conex or Sea vans containers) has been developed for several rearing programs in the US including PBW, light brown apple moth, Tephritid fruit flies and parasitoid wasps. The cost of an 8 x 40 ft. (320 SF rearing space) container supplied with electrical and HVAC is about $20,000 USD. Units such as these could also be developed for pathogen production or parasitoid species production and would allow the isolation of these operations from the main production facility.

Any species considered for production by OKSIR would require regulatory approval by CFIA. The best species for production would be for those that already exist in the region or could not survive the winter months.

Of all the options for program expansion, adding additional species for sterile production would probably be the most technically difficult, and would require a large investment in R&D to develop.

Recommendations

Program Management and Strategy

- There is a need for an overall strategic program plan/approach for the delivery of services, with operational decisions based on survey data (damage and moth capture). Operations should use a combination of flexible tactics, the choice of which is based on sound scientific data (SIT, SIT/MD, variable release rates, sanitation, and banding, etc.)
- Based on the experience with previous successful area-wide SIT programs, area-wide SIT releases are recommended for the whole Okanagan Valley during the entire season as a permanent suppression tool. Problem areas should be addressed with additional tactics.
- The suggested area-wide treatment strategy for 2015:
    - Suggested blanket release rate for entire valley = 1 dish/acre/week
    - Zone 2 & 3 hotspots (and defined surrounding area) = 2 dishes/acre/2x week + additional tactics
    - Zones 2 & 3 integrate SIT with mating disruption in all orchards
- Program protocols should be formalised that clearly define objective and transparent thresholds and triggers used to classify orchard priority levels and risk categories. These risk categories should identify hotspots and trigger additional tactics, including additional releases. Identified hotspots should be treated as a part of a bigger area.
- Field service representatives should be engaged to help develop the threshold treatment levels and associated management and spray recommendations.
- An annual technical meeting should be organised to review the program and engage stakeholders in program delivery. This should ideally include international technical experts in addition to local technical support (e.g. Washington Field Service)
- Program should forge and strengthen academic ties with local and international universities to target applied research, address program needs, and identify potential staff.
- Project management is encouraged to continue international promotion of the program to benefit from information flow, increase technical capacity, and increase brand recognition, especially if expansion of scope or scale is being considered.
- The organizational structure should be redefined, with the OAC reporting to the GM of OKSIR, who in turn reports to the board of directors.
- A technical committee (different from the OAC) should be formed to advise program management on strategic decision making (suggested membership: field service reps, industry reps, area-wide control specialist, SIT specialist, IPM specialist, Chair of the committee should be independent from the political board).

Recommendations continued

Program Operational Decisions

- Program should consider eliminating the zone designation and managing based on smaller neighbourhood units, with units based on common agricultural and ecological characteristics.
- Program should use existing GIS data to analyze block size, proximity to residential areas, and degree of isolation from other blocks.
- Program needs spray records and analysis to evaluate program efficacy and cost-effectiveness.

Program Staffing

- **Priority 1**: Need a full-time operational entomologist/IPM specialist to serve as technical director. Until this person is in place, consider contracting technical advice for the 2015 season with special attention to hot spots and possibility of combining MD/SIT to increase suppressive pressure in hotspot areas.
- **Priority 2:** Need full-time methods development entomologist in the rearing facility in Osoyoos, especially if program is to expand scope or scale of rearing operations
- Program needs succession planning for all key full-time positions
- Extension training required for field staff

Program Delivery

- The program should develop a communication plan around the strategic plan for the delivery of services—communicating to both technical and non-technical audiences,
  - Need engagement strategy for growers to increase grower understanding, buy-in, and compliance (facility tours, etc.).

Rearing Facility

- Plan upcoming year's rearing production based on the program strategy
  - Need a back-up generator for essential service areas of the facility

Radiation Source

» The program must replace the current irradiation source within a timeframe that accommodates the future scope and strategic direction of the program (2-5 years). Refurbishing or recharging the current machine is not recommended, as the age of the machine makes mechanical failure probable.

» Replacement with current x-ray technology is not recommended. The machines currently available are not reliable for use in an operational mass-rearing program.

Safety and Security

» Sterilization process should be better streamlined to increase biosecurity in the rearing facility

Transport and Release

» Evaluate feasibility of aerial release system for codling moth and evaluate its cost/benefit

» Consider approaching IAEA for technical assistance/advice setting up field trials on efficacy and moth quality through aerial releases

» Evaluate modifications to the ATV moth release device (e.g. canister oriented towards canopy rather than horizontally, warming in canister system before release, use of a warm-up compartment before release)

» Some of the equipment (ATVs, cooler boxes) are showing wear and need to be replaced in order to maintain continued on-time delivery of high-quality insects

Monitoring Program

» Analyze the efficacy of the buffer zones

» Combine survey and spatial data to analyze hotspots including the potential impacts of urban and feral trees. In the high-prevalence areas, do more focused analysis on possible root causes (poor management, poor sanitation, feral source population, etc.)

» Program should employ an ongoing robust, scientific sampling plan that may combine pre-harvest damage data, trap data, and band data, with two objectives:

1. evaluate overall program efficacy, with consideration of existing data set to ensure some degree of continuity
2. make operational decisions

» Program should consider setting up cull data sampling program

» Program should track the number of orchards that meet the program goal of having less than 0.2% damage

Recommendations continued

Quality Control

- Implement field quality control protocol assessing 1) temperatures throughout the moth delivery process 2) quality of insects at arrival to release site
- Develop quality control protocols for ensuring quality of moths during export process and establish export quality standards

Future Program Directions

- To ensure long-term sustainability of the program, the program should evaluate possible expansions of scope and/or scale to diversify and supplement revenue streams. Pursuing any of these strategies would require full technical support and outside expertise.
- Possible scale expansions
    - Sales of codling moth to other markets, off-season sales, excess capacity, etc.
- Possible scope expansions
    - Management scope—monitoring for other pest species as part of existing area-wide monitoring
    - Product scope—rearing a second pest sp.
    - Virus production
    - Biocontrol agents
    - Use modular buildings to support rearing of different species