Area wide management of fruit fly - Central Burnett

Annice Lloyd
QLD Department of Primary Industries & Fisheries

Project Number: AH03002

AH03002

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AREA WIDE MANAGEMENT OF FRUIT FLIES CENTRAL BURNETT

Horticulture Australia Project Number AH03002

FINAL REPORT (AUGUST 2007)

Annice Lloyd *et al.*
Market Access Team
Horticulture and Forestry Science
Department of Primary Industries & Fisheries

Queensland Government

CentralBurnettHorticulturalCouncilInc.

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PROJECT DETAILS

Horticulture Australia Ltd Project Number : AH03002

Project Title: Area wide management of fruit fly - Central Burnett

Report Date: August 2007

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Project Objective:
To improve fruit fly control in the Central Burnett, Queensland's major citrus production area, by trialling an area wide management program.

Funding: Department of Primary Industries and Fisheries, Queensland
Horticulture Australia Ltd.
AusHort
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In-kind contributions from Gayndah and Mundubbera Shire Councils

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1 MEDIA SUMMARY

A recently completed project undertaken by the Queensland Department of Primary Industries and Fisheries (DPI&F) has shown that area wide management (AWM) of Queensland fruit fly can greatly improve control of this serious pest. Fruit fly is a major market access barrier for many fruit and vegetable crops and any strategies which improve field control can provide economic benefits for growers and have the potential to enhance market access opportunities.

The AWM program carried out in Queensland's major citrus production area in the Central Burnett was planned, developed and implemented by a management committee which included DPI&F researchers, citrus and table grapes growers, shire council representatives and Central Burnett crop consultants. The program was aimed at improving fruit fly control in major commercial crops in the district (citrus, table grapes and mangoes) and at implementing, for the first time, fruit fly control measures in the town backyards of Gayndah and Mundubbera. These town areas contained many fruit trees which had been identified as breeding "hot spots" for fruit fly which contributed to high fly populations across the district particularly in spring and early summer.

The AWM program, known locally as the "Fruit Fly Force", involved extensive grower education and community engagement activities which began six months prior to the official commencement of the project in July 2003. As a result, there has been excellent support from the Central Burnett community. Growers provided voluntary contributions for matching by Horticulture Australia to fund the program. Under the guidance of local crop consultants, approximately 90% of commercial growers adopted the recommended control methods. In Gayndah and Mundubbera, 89% of town property owners were willing to participate in some way.

The control methods employed in orchards and in the town areas were regular protein baiting of host trees and the distribution of male annihilation technology (MAT) devices (wicks dosed with male lure and insecticide which attract and kill male flies). These strategies have been very effective resulting in 95% reduction in peak trap catches across the district and infestation in backyard fruit in town areas being reduced from 61% to 22%. It is hoped that this additional level of fruit fly field control will enhance market access opportunities for all Central Burnett growers in the future.

The success of the program to date has prompted the Central Burnett AWM Committee to initiate an ongoing, industry funded project to maintain AWM. The DPI&F research team is now working with producers of other fruit fly host crops to see if similar AWM strategies can be adapted to other horticultural production areas where Queensland fruit fly is a major problem.

2 TECHNICAL SUMMARY

This project has demonstrated for the first time in Australia that area wide management (AWM) of Queensland fruit fly (*Bactrocera tryoni)* is possible in a major horticultural production area where fruit fly is a year round endemic pest. The study area was Queensland's major citrus production region in the Central Burnett, an area of approximately 70km by 12km along the Burnett River and surrounding the towns of Gayndah and Mundubbera. The area includes approximately 2000 hectares of citrus across 71 orchards, 370 hectares of table grapes and 50 hectares of mangoes.

For many years, protein baiting, as a component of a well established Integrated Pest Management program, had provided a high level of fruit fly control in citrus which is primarily a winter crop. However, fruit fly control in the summer commercial crops such as mangoes and table grapes was not as well coordinated. In the past, there had been no attempt to control fruit fly breeding in town areas although there were many fruit fly hosts trees in backyards in Gayndah and Mundubbera.

The AWM program, known locally as "The Fruit Fly Force", was planned, developed and implemented by researchers from the Queensland Department of Primary Industries and Fisheries (DPI&F) working with a committee of local crop consultants and representatives from the citrus and table grape industries, and from local government authorities and other stakeholder groups. The scientific basis for the project was extensive prior research undertaken by DPI&F in the Central Burnett. The aims of the project were to improve fruit fly control and market access opportunities for all fruit fly host commodities grown in the district. The targets for AWM were the seasonal rapid increase in fruit fly numbers in early spring and the high level of summer infestation which had been identified in untreated fruit in town areas. The primary on-farm strategies adopted were to improve protein baiting practices and to implement year round Male Annihilation Technology (MAT) in the form of area wide distribution of MAT devices (wicks dosed with cue lure and insecticide). The main focus in the town areas of Gayndah and Mundubbera was to introduce year round MAT and targeted baiting of fruiting host trees, both of these activities being undertaken by local council operators funded by the project.

The recommended AWM strategies have been well supported by the Central Burnett community with 90% of growers and 89% of town property owners becoming involved in the program. Since July 2003, fruit fly pressure across the entire district has been greatly reduced. Peak trap catches (using cue lure attractant) have been reduced by 95% and overall infestation in backyard fruit in town areas has been reduced from 60.8% to 21.8%. Citrus and non-citrus growers have reported significant improvement in fruit fly control.

Central Burnett stakeholders have decided that the program will continue as a long term, industry funded activity. It is anticipated that the additional level of phytosanitary security provided by AWM will enhance both domestic and export market access opportunities for Central Burnett commodities in the future. Other horticultural areas are now seeking to use the Central Burnett program as a model for implementing AWM strategies for Queensland fruit fly.

3 INTRODUCTION

3.1 Features of fruit fly area wide management programs

Area wide management (AWM) programs for fruit flies of economic importance have been implemented around the world for several decades (Tan 2000). The objective of all AWM programs is to reduce the pest population within the target area to a non-economic level by attacking the entire pest population in the target area (Lindquist 2000). This contrasts with conventional insect pest control methods which aim to protect susceptible commodities from infestation.

There are a number of features which are common to all area wide management programs for fruit flies (Hendrichs 1996, Lindquist 2000, Jorgensen 2002). These include the following:

- The program covers a relatively large defined area.
- Numerous individual producers are involved.
- The target area for the pest includes commercial host production areas, other rural areas and urban areas adjacent to production areas.
- AWM programs take into account applied components as well as the natural factors which contribute to controlling fruit fly numbers (*see below*).
- AWM programs should be based on known pest activity in the target area.
- An area wide approach enables implementation of specialised methods of control which may not be economically feasible or effective on an individual property basis.
- Operational organisation is required to treat non-commercial production areas (eg. urban areas)
- Effective AWM requires a management body representing all stakeholders.
- A high level of stakeholder commitment is required.
- AWM is a long term approach requiring long term funding.

Natural factors which may contribute to AWM of fruit flies include the following:

- ***Climatic conditions*** – Temperature extremes (either low or high) can reduce and even temporarily eliminate fruit fly populations in an area.

- ***Alternative hosts*** – Presence of cultivated, native and feral hosts outside of commercial host production areas can influence fruit fly populations.

- ***Crop susceptibility*** – Host fruits differ widely in susceptibility due to seasonality of the crop, the stage of maturity at harvest and inherent qualities of the fruit (eg. skin resistance to oviposition, flesh suitability for immature development). Host plant characteristics such as the nature of the foliage for shelter and height above ground may also influence attractiveness to fruit flies.

Applied components which may contribute to AWM of fruit flies include the following:

- Treatment of host plants in commercial production.

- Treatment of host plants in urban areas and in rural areas adjacent to commercial production.

Treatment strategies include:

- Insecticide cover sprays and/or ground sprays
- Protein bait sprays
- Male Annihilation Technology (MAT)
- Sterile Insect Technology (SIT)
- Biological control (natural or released populations of fruit fly parasitoids)
- Treatment of overwintering sites
- Trap crops (planting and treatment of perimeter crops attractive to fruit fly)
- Removal of unmanaged hosts
- Fruit sanitation (in commercial production and in urban areas)
- Quarantine regulations to restrict movement of host fruits into the AWM area

3.2 Fruit fly area wide management in Australia

In Australia, AWM programs have been aimed primarily at dealing with exotic incursions (eg. papaya fruit fly in north Queensland in 1995), maintaining freedom from endemic fruit flies in certain horticultural production areas (eg. ongoing Fruit Fly Exclusion Zones in southern states, eradication of Queensland fruit fly from Western Australia 1989) and ongoing population suppression in buffer zones around exclusion areas. Although there has been extensive research on field control across all areas in Australia where fruit flies are endemic, there has been no attempt in the past to implement a large scale area wide management program in an area with moderate to high endemic populations of a pest species. The features of AWM as listed above must be taken into account for any such program to be successful.

The potential value of AWM for endemic pest species was identified as a high priority by researchers and industry representatives at a national fruit fly R&D meeting convened by Horticulture Australia Ltd (HAL) in 2001. Consequently in 2002, HAL commissioned an external consultant (Keith Jorgensen) to undertake a national review across all states to identify horticultural production areas with endemic fruit fly issues (either Queensland fruit fly, *Bactrocera tryoni,* or Medfly, *Ceratitis capitata*) where AWM programs could be appropriate. Nine areas were evaluated against a set of relevant criteria for successful AWM and were ranked in order of potential success (Jorgensen 2002). The Central Burnett district of Queensland was ranked as the area with the highest potential for successful implementation. The five top-ranked districts were invited by HAL to submit applications for support funding under this implementation project. As a result of this process, funding was approved in July 2003 for pilot AWM programs to be undertaken in the Central Burnett District in Queensland by the Department of Primary Industries and Fisheries (DPI&F) and in Narromine, Orange and Young areas of New South Wales by the New South Wales Department of Primary Industries (NSW DPI). The Central Burnett (CB) program (HAL Project AH03002) was the largest of those approved involving a significantly greater number of growers and higher project funding (approx. $1.1M over three years).

3.3 Central Burnett horticulture

The following background information demonstrates the features of the Central Burnett region which were taken into account in the Jorgensen Report (2002) and which indicated that there was a reasonable chance of implementing a successful AWM program.

3.3.1 The citrus industry

The Central Burnett district is the major citrus production area in Queensland (Fig.1). Production figures for the Queensland citrus industry in 2000 show that of a total 117,446 tonnes of citrus, 76,180 tonnes were sold on the domestic market, 8,414 tonnes were processed and 21,137 tonnes were exported. Mandarins make up the largest share of production accounting for approximately 70%, with most of these being grown in the Central Burnett district. The gross value of citrus production in Queensland in 2000 was $120m. The detection of citrus canker in Emerald in 2004 and the subsequent eradication program and loss of production from that area has had a very serious impact on the Queensland citrus industry in recent years. The Central Burnett district was not affected by citrus canker but loss of some export markets due to other issues and prolonged lack of rain had adversely affected the industry in south east Queensland. However, by 2006, domestic markets had improved and it was estimated that the Queensland citrus industry had returned to a production value of approximately $120m (pers. com. Chris Simpson, Queensland Citrus Growers).

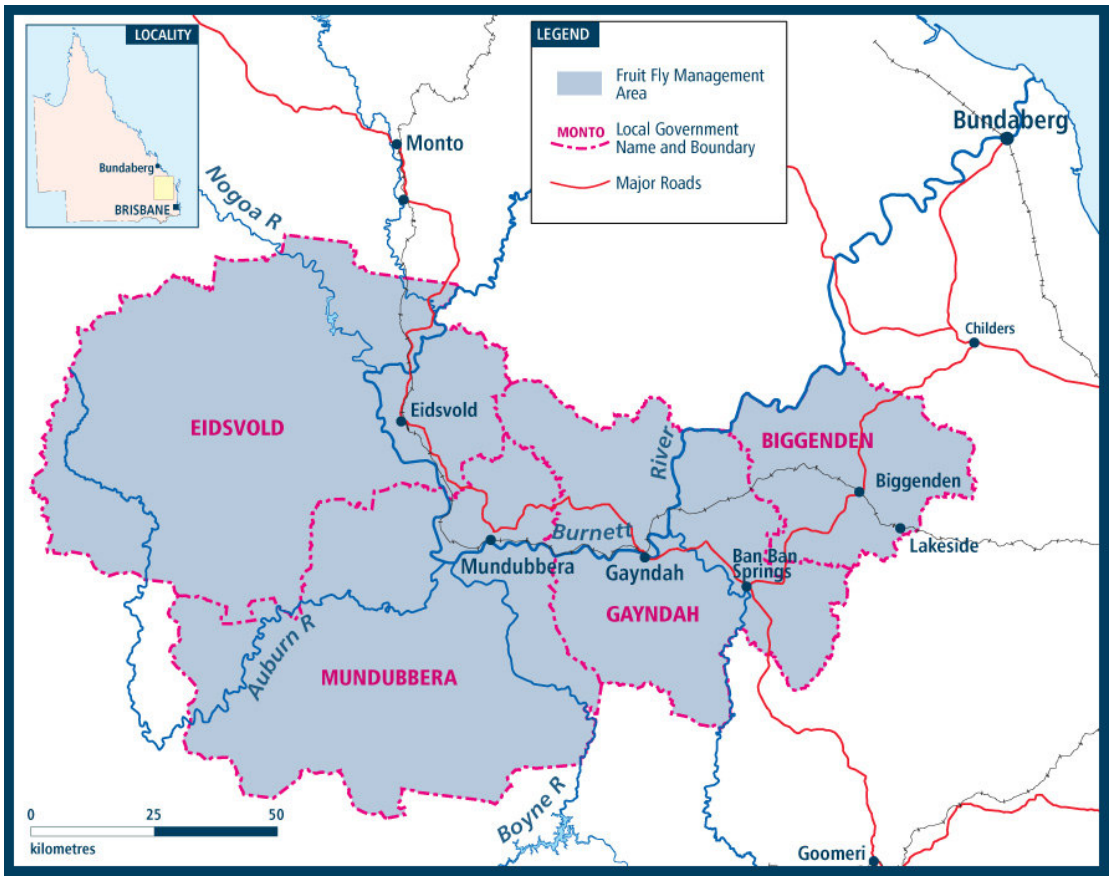

Fig. 1. Map of the Central Burnett fruit fly management area.

The total area growing citrus in the Central Burnett is estimated to be in excess of 2,000 hectares spread across 71 orchards. Citrus is by far the major crop grown in the district with smaller plantings of grapes, peaches, nectarines, avocados and mangoes. The Central Burnett district is centred on the towns of Gayndah (pop 2,500) and Mundubbera (pop. 2,000) in the Burnett River Valley. This district is approximately 270km north-west of Brisbane and is 70km long and 12 km wide. Most orchards are located along the high banks of the Burnett River and its tributaries. A few orchards are on elevated well drained sites away from the river.

In the Gayndah area some 34 of the 40 growers are members of the Gayndah Packers Co-operative Association Ltd (Gaypak). Most Gaypak growers have smaller citrus plantings of around 20ha. There are also about 10 "independent" producers in the Gayndah area averaging 30ha citrus plantings. Mundubbera has one major corporate producer and about 16 "independent" producers. The larger established independents average 120ha and there are a number of smaller growers in the district averaging about 50ha.

The Queensland citrus industry is mainly oriented towards the fresh fruit market with little reliance on the processing sector. In 2000, Queensland exported 21,137 tonnes valued at $28m. The majority of citrus exports are from the Central Burnett. Current export markets include Hong Kong, Singapore, Indonesia, Japan, Malaysia and Canada. Expansion of export markets to include mandarins to the US is currently a high priority for Central Burnett growers.

3.3.2 Non-citrus horticulture

The main non-citrus horticulture crops in the Central Burnett are mangoes and table grapes with 95% of the district production of these two commodities being grown in the Mundubbera shire. There are approximately 50ha of mangoes involving 12 growers. Ninety percent of mango production comes from five growers and three of these are also large citrus producers. Mangoes in the Central Burnett are harvested from the second week in January to late February. Approximately 370ha of table grapes are grown in the district by 30 growers of whom 13 are also commercial citrus producers. Most grape producers have less than 10ha under production but one producer has 150ha. Grapes in the Central Burnett are harvested from late November to late January. Fruit flies are a serious problem in both mango and grape crops if regular baiting and/or insecticide cover sprays are not applied. The harvesting period for both crops is in the summer months when fruit fly pressure is high.

3.3.3 Fruit fly management prior to AWM

Fruit fly control in citrus in the Central Burnett has for many years been an important component of a well established Integrated Pest Management (IPM) program which began in the district more than twenty years ago. IPM utilising natural and augmented populations of beneficial insects to control insect pests other than fruit fly is now widely implemented. This has led to a 75% reduction in pesticide and miticide usage in citrus pest management (Smith et al. 1997). Approximately 90% of growers follow the recommended practices employing local crop consultants to provide pest monitoring services. These pest consultant businesses employ a total of 13 staff and beneficial insects for release in orchards are reared and supplied by the Mundubbera based company, Bugs for Bugs.

Fruit fly activity in citrus production in the Central Burnett has been well documented through trapping carried out by local crop consultants for approximately two decades. The main fruit fly control strategy has been regular protein baiting supplemented by occasional insecticide cover sprays (eg. dimethoate) at times of high fly pressure. Because citrus is harvested between March and October, except at the beginning and end of the season, much of the crop is not exposed to high fly pressure experienced during the summer months. Since 1997, additional extensive field trial, trapping data and host fruit survey data has been obtained in projects conducted by DPI&F researchers (Lloyd et al.2000, Lloyd et al. 2003).

Prior to AWM, a combination of geographic factors, climatic conditions and on-farm fruit fly controls resulted in very low fruit fly numbers across the entire Central Burnett district during the winter months when most of the citrus crop is maturing and susceptible to fruit fly attack. From 1997-1998, DPI&F researchers sampled more than 60,000 citrus fruit to show that infestation levels in commercial orchards were extremely low during most of the citrus season. As a direct result of this research, an interstate quarantine protocol was developed and implemented in 1999 under the Interstate Certification Assurance (ICA) scheme. This protocol (ICA-28) allows Central Burnett citrus to enter Victoria on the basis of preharvest baiting and postharvest inspection during the period March to late August. This protocol avoids the need for postharvest chemical treatments with dimethoate, which are currently required by other states. Almost all citrus growers follow the field control procedures in this protocol although many continue to apply postharvest dimethoate treatments which enable fruit to access all domestic markets.

During the planning stages for this project, a significant driving factor for the implementation of an AWM scheme was the likelihood that the chemical postharvest treatment (dimethoate), currently used to access most interstate markets, would not be acceptable or available in the future. Now that the APVMA (Australian Pesticides and Veterinary Medicines Authority) review of this chemical is almost completed, and restrictions on some current dimethoate uses are imminent, it is even more imperative that alternative treatments are available to maintain access to markets which currently rely on dimethoate treatments. The security of systems approach protocols such as the current ICA-28 would be enhanced by effective AWM, thus increasing the likelihood of wider acceptance of such protocols by other domestic markets.

3.4 The Central Burnett AWM program

3.4.1 Scientific basis

For many years regular weekly baiting from January to September has been employed in most citrus orchards in the Central Burnett to maintain an acceptable level of fruit fly control. However, low levels of breeding have been found to occur during winter, particularly in untreated backyard citrus in town areas (Lloyd *et al*. 2000). A very rapid increase in fruit fly numbers occurs across the entire district at the end of the citrus season in late August to early September. This population explosion could be due to reduced baiting as many citrus blocks have been harvested by that time in the season, or the effect of increasing temperatures on fly breeding and/or responsiveness to male lures. This spring fly pressure increases the risk of infestation in the high value, late season Murcott mandarin crop.

When the citrus crop has been fully harvested, the most common commercial fruiting hosts available during the summer months are table grapes, stone fruit and mangoes. In 1999, DPI&F fruit fly researchers carried out a district wide fruit survey which showed that there are very few wild or feral hosts in the citrus growing areas (Lloyd *et al*.2000). However, there are large numbers of summer fruiting hosts (loquats, mangoes, stonefruit) in the backyards in the town areas of Gayndah and Mundubbera. As these hosts are largely untreated, they represent "breeding hot spots" which generate high fly populations which threaten summer commercial crops and carry over into the next citrus season. These untreated urban hosts were a primary focus in planning the most appropriate AWM strategies.

3.4.2 Project aims

- To improve fruit fly control across the entire district by implementing additional control strategies in commercial orchards and by implementing controls in the town areas for the first time.
- To specifically target the spring fruit fly population explosion in the Central Burnett district in the hope that reducing fly numbers at this time will significantly reduce fly pressure at the beginning of the next citrus season in January and eventually lead to an overall reduction in fruit fly pressure throughout the year.
- To minimize breeding in summer fruiting hosts particularly in town areas.
- To use AWM as a component in a systems approach to achieving quarantine security to expand current interstate and export markets.

3.4.3 Defining the area

For the purposes of this project, the area to be subject to AWM strategies was approximately 70 km long by 12 km wide along either side of the Burnett River as it crossed the citrus growing region from east to west. The area included the shires of Gayndah and Mundubbera and parts of Eidsvold shire to the west and Biggenden shire to the east. The two towns in the centre of the citrus production area, Gayndah and Mundubbera, were the only town areas included in the AWM program.

3.4.4 AWM strategies

The strategies employed to achieve the above objectives were based on improvements in the existing baiting procedures and the introduction of Male Annihilation Technology (MAT) for Queensland fruit fly in orchards and the application of both of these strategies to town areas which were previously untreated. The project planning committee considered that MAT technology would be the most appropriate and cost effective additional treatment for inside and outside orchards. It is a year round, long term control method which is known to reduce male populations to such a low level that female mating is disrupted, which in time leads to significant reduction in pest pressure.

The MAT used in the Central Burnett was based on the distribution of carriers dosed with cue lure and malathion insecticide. Queensland fruit fly (*Bactrocera tryoni*) and its sibling species (*Bactrocera neohumeralis*) are the only economic pest fruit flies in the Central Burnett and constitute 92% and 5% respectively of the total fruit fly trap catches in the region (Lloyd *et al.* 2000). Both of these species respond to cue lure and hence MAT based on this attractant will be effective for both pest species. As an additional orchard control, MAT involves minimal cost and labour, does not require

frequent application, is not disruptive to IPM, and has no adverse crop effects (eg. phytotoxicity, fruit residues). MAT is also a highly appropriate treatment for urban areas because of its low environmental impact, community acceptance, and ease of application and withdrawal (if required).

3.5 Preliminary research related to AWM

Prior to commencement of the AWM project, extensive DPI&F research was undertaken in other projects over a number of years providing base line data on fruit fly activity in the Central Burnett which was essential for planning and developing an AWM program (Lloyd et al. 2000, Lloyd et al. 2003).

3.5.1 Infestation in commercial citrus prior to AWM

Research, undertaken by DPI&F in 1997-1998, assessed fruit fly infestation in commercially produced citrus prior to any AWM strategies. Results showed that infestation levels in 55,000 fruit comprising a number of varieties were extremely low (less than 0.029 – 0.047% at 95% confidence) from March to late August. On this basis, an interstate market access protocol based on preharvest protein baiting and postharvest inspection (ICA-28) was developed. This protocol, which has to date been accepted by Victoria only, has been operational since 1999 with no fruit fly detections in any fruit sent under this system. The data generated in this research were highly relevant to planning AWM and clearly demonstrated that infestation in commercially treated citrus would not be a practical or economical method for evaluating the efficacy of AWM strategies.

3.5.2 Area wide trapping prior to AWM

A district wide survey monitoring 51 cue lure traps for twelve months commenced in February 1999 and provided extensive data on the seasonality of fruit fly populations in the Central Burnett. Results identified similar peaks of fly activity in early spring across all locations including treated orchards, untreated town areas, and along the Burnett River, the main watercourse in the area. Further trapping studies carried out from August 2002 to August 2003, using 40 cue lure traps showed the seasonal pattern was remarkably similar from year to year. These projects provided important base line data which confirmed that the rapid increase in fly activity in early spring and breeding in summer hosts, particularly in town areas, were the most appropriate targets for AWM strategies.

3.5.3 Host fruit surveys prior to AWM

As part of a district wide survey of fruit fly activity in 1999, 253 samples of non-commercial fruit representing 49 different plant species were collected and assessed for infestation. This survey focused on potential wild hosts in the district and fruit collections were made along water courses and in other areas of native vegetation. Results showed there were relatively few wild hosts in the area and none was likely to contribute significantly to fruit fly numbers. A later survey in 2002-2003 concentrated on potential summer hosts in the town areas of Gayndah and Mundubbera. Of 92 samples of 12 potential host fruits, 60.8% were found to be infested with fruit fly. The most heavily infested hosts were mulberries, Brazilian cherries, loquats, cherry guavas, and stonefruit which showed infestation in 100% of samples. Of 5,293 flies reared from fruit, 99.5% were *B. tryoni* with the remainder being *B. neohumeralis*. A

quantitative survey of host trees in town areas of Gayndah and Mundubbera identified mangoes as the most common backyard tree with citrus being the second most common. These results provided important information for targeting breeding hot spots in an AWM program.

3.5.4 Comparison of MAT carriers

This research (Lloyd et al. 2003) involved comparing the efficacy of two MAT carriers, cotton wool wicks dosed with 1ml of cue lure and 1ml of Maldison 500 (as used in monitoring traps) and small Cane-ite squares dosed with 1ml cue lure and 0.5ml of Maldison ULV which equated to the same quantity of active ingredient (malathion) as in the wicks. Over a period of 36 weeks weathering in the Central Burnett, the relative efficacy of both carriers compared to newly dosed carriers of each material decreased to approximately 60%. Although results were very variable, there was no evidence that one carrier was more effective than the other over time. This information was the basis for the decision to employ the same cotton wool wicks, as used in monitoring traps, as the MAT carriers in the AWM program.

4 PROJECT MANAGEMENT

When planning for this project was initiated there were two local grower organisations in the Central Burnett district, one based in Gayndah and the other based in Mundubbera. Growers in both areas contributed levies to a research and development fund administered by the Central Burnett Horticulture Committee (CBHC), which consisted of representatives from both the Gayndah and Mundubbera groups. The CBHC contributed funds to several DPI&F fruit fly research projects which provided baseline data used in the development of this AWM project.

4.1 Central Burnett Area Wide Management Committee

At a meeting in May 2002, the Central Burnett Area Wide Management Committee (CBAWMC) was formed as a sub-committee of the CBHC specifically for the purpose of developing a HAL project proposal for an AWM program and implementing the program, if and when funding was approved. The CBAWMC consisted of the DPI&F research team members, the three local crop consultants in the Central Burnett, a Shire Council representative (the Environmental Health Officer for Gayndah and Mundubbera), citrus and non-citrus grower representatives from both Gayndah and Mundubbera grower groups, and other industry stakeholders (packing shed supervisor and local CitGroup coordinator).

The Central Burnett AWM project proposal was based on a funding arrangement approved by HAL by which the project voluntary contribution was raised each year by growers contributing in advance the cash value of the fruit fly control materials which were to be applied on their properties (ie protein baits, insectide and MAT carriers). Equipment and labour costs were not included. The CBAWMC provided an estimated cost per hectare for the main fruit fly host crops (citrus, table grapes, stone fruit and mangoes) as a guide for growers to calculate their contributions depending on the hectares of each crop in their orchards. Once the project commenced,

contributing growers would then purchase their fruit fly control materials through local commercial suppliers who would charge these costs to the project.

4.2 Funding

Prior to matched funding being available from HAL, the local grower associations in both Gayndah and Mundubbera contributed $10,000 to the CBAWMC to fund project development activities. When the project proposal and funding mechanism was approved by HAL, the CBHC become incorporated as the Central Burnett Horticulture Council Inc. to manage the local financial aspects of the project and the project team set about raising the required funds from growers. The local crop consultants who collectively serviced approximately 90% of growers in the district provided invaluable assistance in the timely collection of funds from growers. A local professional book-keeper was employed by the project to manage growers' contributions and to be responsible for maintaining CBAWMC financial records once the project had commenced.

The target voluntary contribution from growers for the first year ($227,000 from 48 growers) was achieved by the required date. The Gayndah and Mundubbera Shire Councils each contributed $10,000 in kind to the project. When the project commenced in July 2003, HAL matched funds were paid to DPI&F as the lead agency. An agreed proportion of these funds was transferred to CBHC Inc. for reimbursement of material costs to growers (as per contributions) and for local operating costs including town treatments, operational staff (Gayndah Shire Council) and promotional activities. The CBAWMC has met on a regular basis during the project and held an annual general meeting each year where office bearers were elected and an externally audited financial report was presented.

Fig. 2. Central Burnett Area Wide Management Committee
L to R Standing: Annice Lloyd, John Owen-Turner, Kristy Neibling, Neil Giddins. Andrew Brown, Ed Hamacek, Ben Harzer, Allan Jenkin, Mal Wallis
L to R seated: Les Darrow, Brian Gallagher, Dan Papacek, Lois Mesner
Absent: Michael Cuvalo, Peter Tucker, Pauline Wyatt

4.3 The "Fruit Fly Force"

At a very early stage in the project, the CBAWMC decided that industry and community engagement in the AWM program would be enhanced by having an easily identified name and logo for the program. Hence the "Fruit Fly Force" came into being. A graphic artist was employed to design a logo and T-shirts bearing the logo were obtained for team members and the local operational staff who were employed by the Gayndah Shire Council to carry out monitoring and treatments in the town areas of Gayndah and Mundubbera.

5 MATERIALS AND METHODS

5.1 Industry and community engagement

For six months prior to the commencement of this project, the project team and the CBAWMC were involved in extensive community and grower education to ensure that all stakeholders in the Central Burnett were informed of the project aims and the funding mechanism. Letters were sent to all rate payers in the district, letter box drops were made to all properties in the town areas, and numerous articles were published in the local media (more details on communication in Section 8).

5.2 Orchard treatments

Prior to the commencement of AWM, there was already a high level of fruit fly control in commercial citrus in the Central Burnett. The introduction of AWM reinforced the importance of the existing strategies in citrus (monitoring, baiting and occasional cover sprays) and recommended adoption of similar strategies in non-citrus crops such as mangoes, table grapes and stone fruit where previous fruit fly control methods may not have been as effective. Although the latter crops together represent less than 20% of the total horticulture in the Central Burnett, as summer crops they fruit at times of peak fruit fly activity, have a greater risk of infestation than citrus and also have the potential to contribute significantly to fruit fly populations which increase the risk of infestation in subsequent autumn-winter citrus crops.

The additional strategy to be implemented for all fruit fly host crops under AWM was the introduction of Male Annihilation Technology (MAT) to target male populations on a year round basis. All growers were responsible for the cost and implementation of control methods on their own properties. Those who had made voluntary contributions to the project had the costs of their fruit fly control materials reimbursed to local suppliers through the project. Widespread adoption of the recommended AWM strategies was greatly facilitated by the fact that most commercial growers in the district were already employing the services of one of the three local crop consultants involved in the AWM program.

5.2.1 Recommended protein baiting methods

The introduction of AWM strategies did not involve any changes to existing bait methodology which had been taking place in citrus orchards. However, the

importance of regular baiting was emphasised and particular effort was made to encourage extension of the same procedures to non-citrus crops such as table grapes, mangoes and stonefruit.

Baiting was recommended on a regular weekly basis from January to harvest for citrus blocks or half fruit growth to harvest for other fruit trees (mangoes, stonefruit). Bait formulations available to growers at the beginning of the project were as listed in Table 1. Application was recommended as a coarse spot or strip spray to the foliage as specified on the insecticide label. Alternating the sides of trees to which bait was applied was recommended to minimise the possibility of any phytotoxicity effects to fruit which came into contact with bait droplets. Growers were strongly advised not to apply bait spray to grass between rows (sometimes done to avoid bait spots on fruit) because baits applied 1-1.5m above ground have been shown to attract approximately 30 times more flies than baits applied to grass at ground level (DPI&F unpublished data). When MAT was being used, it was recommended that the timing of bait application needed to be based on fruit susceptibility rather than relying solely on male trap catches as an indicator of fly activity.

Table 1. Fruit fly bait options for commercial orchards in 2003.

Water +	**Fruit Fly Lure** (autolysed protein)	**+**	**Chlorpyrifos** 750g/kg Lorsban 750 WG	**OR**	**Trichlorfon** 500g/L Dipterex 500 SL	**OR**	**Maldison** 1150 g/L Hy-Mal
100 L	2 L		267g		780 mL		435 mL
Recommended rate (as per insecticide product label) Observe with holding period as specified on label. Apply to crop types as per registered use.			50-100ml of mixture per tree as a strip or patch		50-120ml of mixture per tree as a coarse spray		50-100 ml of mixture per tree as a strip or patch For citrus: 15-20L / ha applied as a band at skirt level

Note: Naturalure Fruit Fly Bait Concentrate (Dow AgroSciences) a new, organically certified bait was registered and became commercially available in 2005.

Fig. 3. Typical bait spraying equipment used in Central Burnett citrus orchards.

5.2.2 Recommended Male Annihilation Technology (MAT)

Growers were advised to implement MAT in their orchards as a supplement to baiting. MAT was aimed at reducing the number of male flies on an area wide, long term basis with the eventual effect of reducing female fertility due to the greatly reduced number of males available for mating. The MAT devices used in the program were those produced by the local Central Burnett company, “Bugs for Bugs” (Fig. 4). The same devices were used as lures in monitoring traps (Fig. 5). Marketed as Fruit Fly Cups they consisted of a cotton wool wick mounted in a well on the underside of plastic lid. After some problems with the original design which allowed birds to remove the wicks, a plastic base with holes cut in it was fitted to the underside of the “cup” so that flies could still have access to the wick but the wick could not be easily removed.

Fig. 4. "Bugs for Bugs" MAT cup

Fig. 5. "Bugs for Bugs" trap

Growers were advised to distribute MAT cups at the rate of 10 per hectare in fruit fly host crops and to replace them with new cups three times per year. Old cups could be left in orchards as they were still effective for several months after the recommended replacement period. Old cups were generally removed during pruning before the next

citrus season. During the program, local crop consultants advised growers when cups needed replacing and each round of cups was produced with a different coloured cup so that the age of any cups still in the field could be determined. By August 2003, one month after the commencement of the project, the first round of approximately 25,000 MAT cups had been distributed.

5.2.3 Orchard hygiene

Removal of second crop and residual fruit from orchards was recommended as these fruit could provide ideal breeding grounds for fruit flies particularly after regular baiting had ceased at the end of the commercial harvest period. Harvesting and removal of unwanted backyard fruit (by burying under at least 30cm of soil) from rural residences was also encouraged.

5.2.4 Wild and feral hosts

The district survey which was carried out prior to the beginning of the AWM program showed that there were almost no native hosts and very few feral hosts for fruit fly in and around commercial orchards. However, many rural properties had a variety of cultivated host trees in the house yard and these were frequently left untreated. Under AWM, all property owners were advised to remove feral host trees and to treat other hosts with baiting and MAT cups as per commercial blocks.

5.3 Town activities

The defined area for AWM included the towns of Gayndah and Mundubbera where no previous coordinated attempt had ever been made to minimise fruit fly populations. Preliminary research had shown that heavy infestation in many untreated back yard fruit trees was contributing to high fruit fly numbers particularly in spring and summer. In developing the AWM project, the CBAWM Committee negotiated with the Gayndah and Mundubbera Shire Councils for council employees paid by the project to undertake all program activities in the two town areas. The cost of all materials, equipment and vehicle used for town treatments was met by the project.

Fig. 6. Gayndah Shire Council staff (Neil Giddins and Kristy Neibling) responsible for town treatments and monitoring activities with the Fruit Fly Force vehicle.

5.3.1 Preparation for town treatments

Prior to commencement of AWM activities, permission to enter private property forms (Appendix 3) were distributed to all property owners in the town areas of Gayndah and Mundubbera. Signed forms were collected to record permission to enter, to install MAT cups or traps, to apply bait sprays and to collect fruit. All of this information was entered into the AWM database held at DPI&F Indooroopilly. Across both towns, of 699 property owners approached, 624 (89%) agreed to participate in the program in some way. Five hundred and ninety-four property owners gave permission for MAT, 430 for bait application, 355 for fruit collection and 75 refused to participate in any way. Baiting was to be confined to properties where there were fruit trees which meant that numerous property owners with no backyard fruit trees were not required to give permission for this activity. The number of participating property owners was lower at the beginning of the program but increased to the level above as the benefits of the program began to be recognised and more residents wanted to participate.

5.3.2 Training of operational staff

In August 2003, the DPI&F team members and the Shire Council representative on the CBAWMC (the Environmental Heath Officer for both Shires) conducted a two day training program for council staff who were to be responsible for all AWM activities in town areas. Local crop consultants and some of their staff also attended. The training covered fruit fly biology and control methods, detailed instructions and practical demonstrations on installing and clearing traps, applying spot bait sprays, distributing MAT cups, fruit collection, safety issues, dealing with the public and recording all program activities.

An Operational Manual prepared by the DPI&F team and containing the following information was provided to all trainees.

- Background information on “what is a fruit fly” and “why does it cause problems for growers”.
- Aims of the AWM program
- Public relations – permission to enter private property, dealing with the community
- AWM strategies in commercial orchards
- AWM strategies in town areas
- Detailed instructions on MAT installation and baiting in town areas
- Equipment and materials required
- Safety issues and instructions – MSDS for chemicals used
- Instructions for installing and clearing traps
- Instructions for fruit collection
- Data management instruction – including the following data recording sheets and how they were to be used
  - Tree location forms (type and number of host trees in town areas)
  - Treatment data sheet (property, contact, presence of fruit trees, permission approved for which activities, any special requirements)
  - Bait Treatment Record – volume mixed, volume applied

- Trap Establishment Sheet – Trap number, GPS reading, location/position description, tree type
- Trap Clearance and Maintenance Record – Trap number, clearance date, trap service (eg new trap, missing/replaced, relocated, new lure wick installed)
- Fruit Collection Data Sheet **–** Sample number, GPS location, location description, plant species and/or common name if known, stage of maturity, fruit from tree or on the ground.

5.3.3 Town bait treatments

The protein bait formulation used in town treatments from July 2003 to late 2005 was as per the registered use for Hy-Mal bait formulation, ie. 43.5ml Hy-Mal + 200ml yeast autolysate protein (Bugs for Bugs Fruit Fly Lure) per 10L water. The bait was applied at the rate of 50ml per moderate sized host tree using a backpack and a hand held sprayer. For larger host trees (eg. many of the mango trees in town areas) bait was applied as 2 or 3 x 50ml spots per tree on a weekly basis**.** Baits were applied to fruiting host trees only on properties where permission had been given. Detailed safety instructions related to mixing baits and applying baits in urban areas were provided in the AWM Operations Manual and demonstrated to council operators at the training course. Baiting was not to be undertaken if it was raining or if wind speeds were in excess of 12 km/h and a Beaufort Scale of Wind was provided to estimate wind speed.

A survey of town areas undertaken prior to the commencement of the program provided valuable assistance to operators in identifying properties where host trees were growing. In late 2005, the new formulated protein bait, Naturalure Fruit Fly Bait Concentrate™ (Dow AgroSciences), became available and was used from that time on in the AWM program for town treatments. Naturalure, which contains protein attractants and the insecticide spinosad, has organic certification in Australia and globally and has zero days withholding period. Although there had been no public concern about the use of traditional bait with organophosphate insecticide in town areas, the CBAWM Committee made the decision to switch to the organic product because of its obvious advantages when treating urban areas.

5.3.4 MAT in town areas

MAT carriers were distributed in the town areas at the rate of one per property where permission had been given and in other likely breeding areas along watercourses or on public land. MAT carriers were replaced four times per year in February, May, August and November. Old carriers were replaced by new carriers each time to minimise visual population in urban areas. As with orchard MAT treatments, colour coding of MAT carriers facilitated distribution records. However, in orchards, carriers were distributed three times per year but at a much higher density than in town areas and old carriers were only removed at the beginning of the next season.

5.3.5 Disposal of infested fruit from urban areas

Property owners in town areas were encouraged to dispose of fallen fruit to minimise fruit fly breeding. Written and pictorial instructions were distributed by a letter box drop to all properties (Appendix 4). Appropriate methods for disposing of fallen fruit such as deep burying or sealing in black plastic bags left for several days in the sun were recommended.

5.4 Program evaluation

5.4.1 Monitoring

The regular monitoring of fruit fly activity using male lure traps in orchards, that had been taking place under the guidance of local crop consultants for many years prior to the commencement of the AWM program, was continued. The male lures were cotton wicks dosed with 1ml cue lure and 1ml of Maldsion 500 secured in a well on the underside of a plastic lid (Bugs for Bugs Fruit Fly Wicks). The plastic device had a hook attached which allowed it to be easily suspended from the lid of the trap which was a modified Lynfield design (Bugs for Bugs Fruit Fly Trap). Wicks were replaced every three months.

Growers were advised to place traps well away from MAT devices as these compete with the wicks in traps. The project team and consultants emphasised to growers that in the initial phase of the program a significant reduction in male trap catches could give a false impression that fly pressure was greatly reduced, whereas in reality, the number of gravid females (and hence risk of crop infestation) may be unaffected. Reduction in the overall population would only occur when the male population has been reduced to such an extent that mating frequency was greatly reduced.

For the specific purpose of evaluating the AWM program, 37 male lure traps were installed across various locations in the district as follows: 5 traps in Mundubbera town area, 6 traps in Gayndah town area, 11 traps in Mundubbera orchards, 6 traps in Gayndah orchards, 3 indicator traps in Binjour area , and 6 indicator traps in rural backyards. The indicator trap sites were specifically chosen to monitor fly activity in locations well removed from treated commercial orchards or treated town areas. They were generally untreated host trees in rural backyards where no baiting or MAT was in progress. The 3 indicator traps in the Binjour area midway between Gayndah and Mundubbera were particularly useful in evaluating the district wide effects of AWM in an area where no treatments were being applied. One indicator site in this area was a large stand of feral stone fruit trees which would normally be highly attractive to any flies in the area.

In town areas traps were placed in known fruit fly host trees and at least 50m from any MAT cups. Traps were cleared on a fortnightly basis by the council operators and by local crop consultants and clearance records and flies were sent in small cardboard specimen boxes to the DPI&F research team at Indooroopilly for counting, identification and recording. On arrival at the Indooroopilly laboratory, trap catches were sorted, identified and counted, with results recorded on the Trap Clearance and Maintenance Record before entry into the DPI&F database.

5.4.2 Fruit collection

Previous DPI&F research showed that infestation levels in commercial orchards which employ regular bait spraying are extremely low (less than 0.029 – 0.047%). Hence, further sampling of very large numbers of commercial fruit would not be warranted to evaluate the efficacy of the additional control strategies that were being implemented under the AWM system. However, infestation levels in primarily untreated backyard fruit in town areas was known to be high prior to AWM, so quantitative assessment of infestation in such fruit (expressed as percent of samples

infested as well as flies per kg of fruit sampled) was a valid and appropriate method for evaluating the effectiveness of AWM.

Collection of fruit from town properties by council operators commenced in spring 2003 and continued until autumn 2007. The previous survey of host trees in town backyards facilitated collection of samples when known hosts were fruiting at different times of the year. Fruit samples were also taken from untreated host trees at the indicator sites mentioned above.

A fruit sample consisted of one type of fruit (eg. peach), at one stage of maturity (eg. green or ripe), taken from one location with details of where the fruit was collected (from tree or fallen on ground). If there were fruit available at more than one stage of maturity (eg ripe on tree and ripe on ground) these were sampled and recorded separately. Where possible, samples of 1-2kg for larger fruit (eg. mangoes or stone fruit) and 20-30 pieces of fruit for smaller varieties (eg. mulberries) were taken. Each sample was placed into a sturdy paper bag (not plastic) and labelled with a unique sample number which was recorded on the Fruit Collection Data Sheet as well as on the bag containing the sample. Fruit samples and relevant data sheets were sent by overnight express to the DPI&F laboratory in Brisbane for processing.

At the laboratory, fruit samples were weighed and the number of fruit in each sample recorded. To determine infestation, samples were held on small gauze-topped containers (drip trays) placed in large ventilated plastic containers with a layer of moist vermiculite in the bottom to act as a pupation medium for any larvae emerging from the fruit. Each collection sample, irrespective of the numbers of fruit in the sample, was held individually. Samples were held at 25-26ºC and 60-70% relative humidity for 2-3 weeks until any fruit fly larvae present had pupated. The vermiculite was sieved on a number of occasions to recover pupae which were then held until adult flies emerged. Flies and any parasitoids which emerged were identified, counted and recorded. All fruit collection results were entered into the DPI&F database.

5.4.3 Grower /consultant feedback

An important non-quantitative evaluation tool used throughout the project was feedback provided by the three local crop consultants who collectively serviced approximately 90% of commercial growers in the district. Consultants monitored fruit fly populations and other insect pest problems in citrus and non-citrus crops and were able to provide up to date information on seasonal fruit fly activity, incidence of crop infestation, and level of adoption of recommended practices.

A more formal evaluation tool was a grower survey conducted at the end of the citrus season in late 2005. This was aimed at identifying any fruit fly control issues, seeking comment on the effectiveness of the AWM strategies and asking growers if they were prepared to support an ongoing program after the HAL project was completed (Details of Grower Survey in Appendix 5).

5.4.4 Infestation in residual and second crop citrus

In December 2004, some growers reported significant fly pressure in summer table grapes crops although the recommended field controls of baiting and MAT were being undertaken. An inspection of one orchard revealed significant numbers of residual and second crop citrus fruit on a nearby block of Murcott mandarins which

had not been baited after the end of the commercial harvest in September. Examination of a small sample of this fruit revealed a high level of infestation (180 flies/kg fruit sampled).

In late 2006, a small scale trial was undertaken to evaluate different methods of minimising these carry over fly populations from the end of season citrus. Removal of all residual fruit at the end of the season was not an economically viable option for large commercial growers. One alternative was to continue to apply regular bait treatments until no fruit remained. Another possibility was the use of released fruit fly parasitoids (*Fopius arisanus)* from a colony established at DPI&F from individuals reared from naturally parasitised, fruit fly infested fruit. This wasp parasitoid lays its eggs into fruit fly eggs thereby having the potential to provide a valuable "mopping up" strategy appropriate for minimising the impact of flies breeding in residual fruit after commercial harvesting ceases.

The trial involved sampling residual and second crop Murcott mandarins from five properties where various end of season strategies had been applied. On two properties, fortnightly bait sprays had been applied to Murcott blocks after commercial harvesting was completed. On two other properties, three parasitoid releases (approximately 5,000 insects per release) were made in the trial blocks between September and November. On the final property, no additional treatments or parasitoid releases were undertaken after the end of the commercial Murcott crop.

A total of 35 samples of fruit (between 5 and 8 samples per property) were collected from the first week in September 2005 to the last week in January 2006. Fruit were held and processed as above to determine fruit fly infestation and parasitism levels.

6 RESULTS

6.1 Industry and community engagement

The support from growers for implementing the recommended baiting and MAT field control methods was particularly good. This was largely due to extensive promotional activities and the involvement of the three local crop consultants who collectively serviced approximately 90% of citrus growers in the Central Burnett. Many of the growers with large grape plantings also grew citrus and several meetings were held at the beginning of the program to target grape growers specifically. Almost all growers serviced by consultants implemented the recommended control treatments of baiting and installation of MAT cups.

The community engagement activities in the town areas of Gayndah and Mundubbera as described in Section 8 were also successful with 89% (624 out of 699) of property owners agreeing to some program activity on their properties. Sixty three percent (441 out of 699) of property owners agreed to baiting or MAT treatments on backyard fruit trees with the remainder agreeing to trapping and/or fruit collection only. Baiting was targeted to backyards containing fruit trees or other fruiting hosts (eg. passionfruit, tomatoes).

6.2 Trapping results

Trapping results following the implementation of AWM need to be viewed in conjunction with data collected in a district wide survey in 1999 which showed the seasonal population variation across the entire district (Fig. 7). This data showed a very significant peak in fruit fly activity (up to 240 flies/trap/day) which started in late August to early September and persisted until December with numbers declining by January.

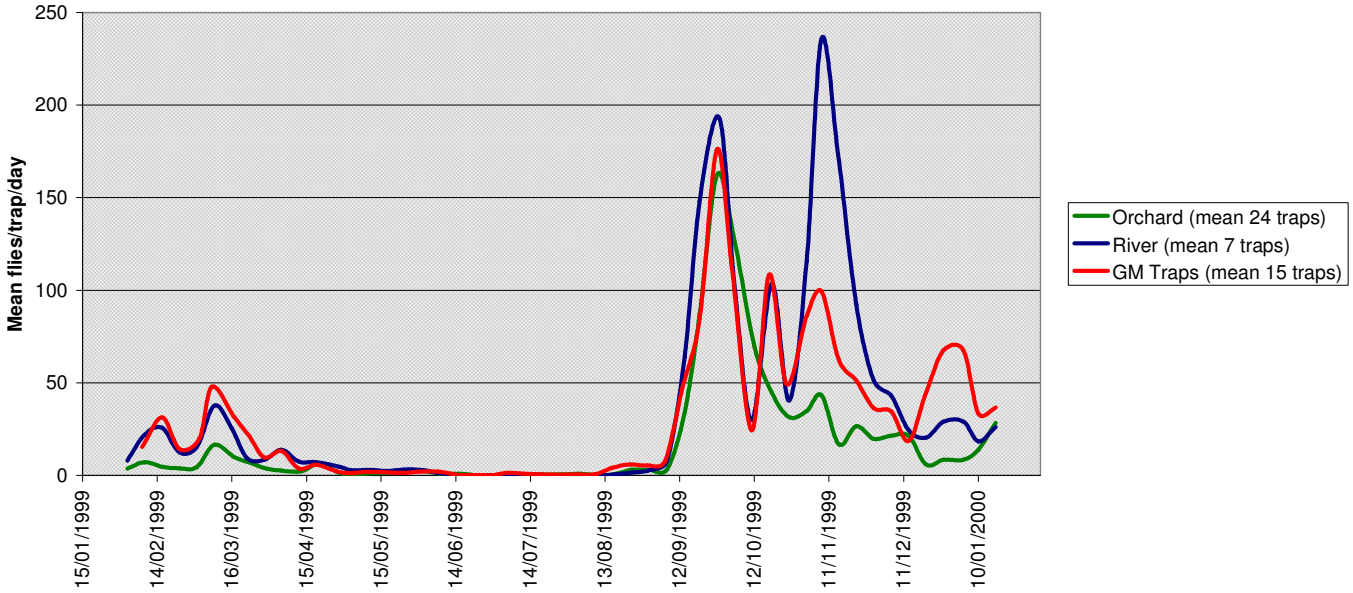

Fig. 7. Fruit fly activity in the Central Burnett based on cue lure trap catches in orchards, along the river and in the towns of Gayndah and Mundubbera (GM traps) from February 1999 - January 2000 (prior to implementation of AWM).

In late 2002 to mid 2003, prior to the start of the AWM project, some growers in the Gayndah area had already started to distribute MAT cups in their orchards. This had an immediate effect in reducing trap catches in all areas where MAT cups were installed. Once the AWM project commenced in July 2003, approximately 25,000 MAT cups were distributed between August and November 2003. This very quickly reduced trap catches across the entire district as shown by numbers in the designated program monitoring traps (Fig. 8). Fly numbers in all 37 traps quickly fell below 10 flies/trap/day (Fig. 8 uses the same scale as the 1999 data in Fig. 7).

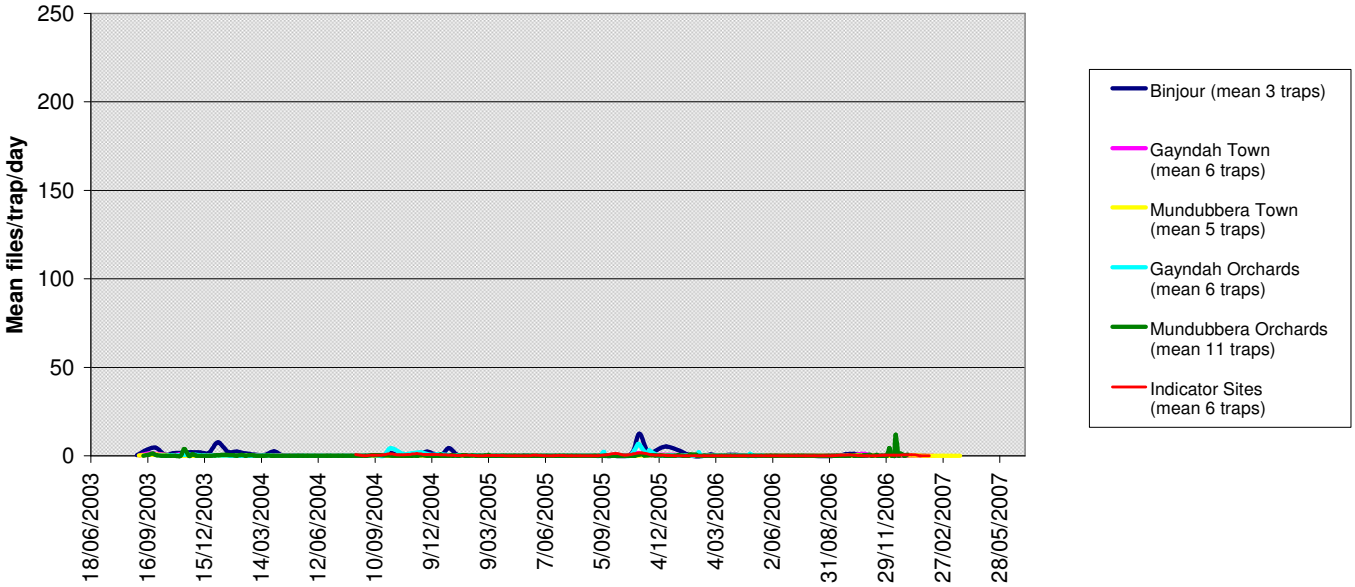

Fig. 8. Cue lure trap catches in the Central Burnett under AWM program June 2003 - April 2007 (same scale as 1999 results in Fig. 7).

From September 2003 until February 2007, all trap catches have remained below 15 flies/trap/day. This represents a reduction of approximately 95% in peak fly trap catches with the implementation of AWM. Results for traps across all types of locations during this period are shown with an appropriately reduced scale in Fig. 9. The seasonal peaks of fruit fly activity between late August and February each year from 2003 to 2007 reflect the same seasonal trends from years prior to AWM but at a much lower level. The highest trap catches under AWM (maximum of 13 flies/trap/ day) were recorded in the untreated stone fruit trees at the Binjour indicator site.

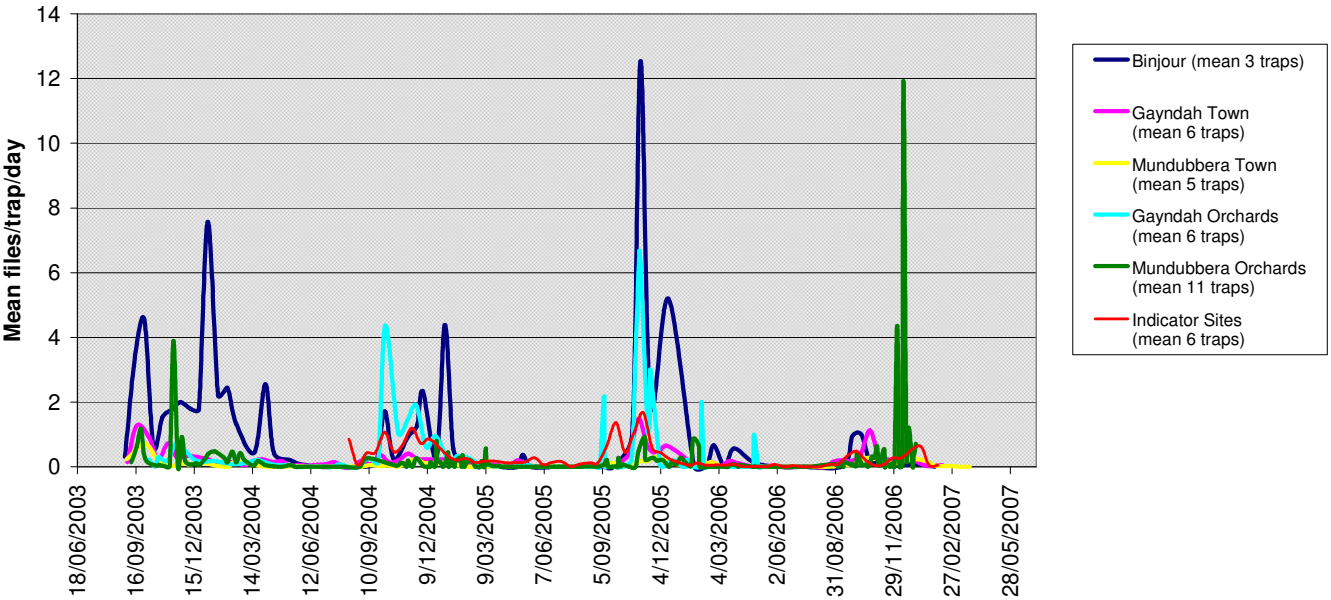

Fig. 9. Cue lure trap catches in the Central Burnett under AWM program June 2003 - April 2007 showing greater detail.

The reduced number of flies at this site in 2006-2007 may have reflected the scarcity of fruit on these trees due to the effects of prolonged drought in the district during this time. Higher fly numbers were found in Mundubbera orchards in late 2006 than in the three previous years. This may have been due to flies breeding in residual and second crop citrus as identified in Section 6.3.1 of this report.

6.2.1 Identification of trap catches

A total of 11,378 flies from 37 cue lure traps across the Central Burnett district have been identified from July 2003 to February 2007. The species identified and relevant proportions of the total trap catch were as follows: pest species *Bactrocera tryoni* (90.6%) and *Bactrocera neohumeralis* (3.5%); non-pest species *Bactrocera bryoniae* (3.6%), *Dacus aequalis* (1.1%), *Dacus newmani* (0.8%), *Bactrocera chorista* (0.2%) and *Bactrocera quadrata* (0.2%).

6.3 Fruit collection

A total of 1,201 samples of backyard fruit from the town areas of Gayndah and Mundubbera have been assessed during this project. The numbers of fruit samples collected and the overall percentages of infestation for each year of the project are shown in Table 2. Data from fruit collection in town areas during late 2002 and early 2003 prior to the commencement of AWM strategies are included for comparison.

Table 2. Fruit collection data from town areas of Gayndah and Mundubbera showing percent of samples infested with fruit fly for each year of the AWM project compared to data collected in 2002-2003 before the project commenced.

Year	Total samples collected	Number of infested samples	% of samples infested
2002-2003 (prior to AWM)	92	56	60.8
2003 – start AWM (Jul – Dec)	70	32	45.7
2004 (Jan – Dec)	395	81	20.5
2005 (Jan – Dec)	403	87	21.6
2006 (Jan – Dec)	260	46	17.7
2007 (Jan – Apr)	73	16	21.9
TOTAL during AWM program	**1201**	**262**	**21.8**

The overall results of fruit sampling (Table 2) showed that AWM strategies reduced fruit fly infestation in backyard fruit from 60.8% prior to the implementation of AWM (Lloyd et al. 2003) to 45.7% during the period July – December 2003. By 2004, overall infestation in town fruit was reduced to approximately 20% and remained at

that level in 2005, 2006 and early 2007. This represented an overall reduction of 65% in infestation in backyard fruit.

Overall 21.8% (262) of samples were found to be infested with fruit fly (Table 2) and 99.2% of these samples were infested with *Bactrocera tryoni* with or without small numbers of other pest fruit fly species (eg. *Bactrocera jarvisi* in 3.4% of samples, *Bactrocera neohumeralis* in 22.9% of samples). Island fly (*Dirioxa pornia*) which is generally only found in over ripe or damaged fruit was reared from 1.9% of samples. Fruit fly parasitoids (*Diachasmimorpha kraussi, Diachasmimorpha tryoni, Fopius arisanus* and some damaged parasitoids unable to be identified) were reared from 34.3% of infested fruit samples. Of the total number of flies reared from infested fruit, *B.tryoni* accounted for 90.4 %, *B. neohumeralis* 1.6%, *B. jarvisi* 0.2% and parasitoids accounted for 7.8%. Over the duration of the program, only nine samples of fruit were found to be infested with *B. jarvisi*, a minor pest species of potential quarantine significance for some markets. This species was not recorded in any trap catches which was not unexpected because it does not normally respond to cue lure.

Results for all fruit species collected in town areas during the AWM project are shown in Table 3.

Table 3. Results of fruit collection in town areas of Gayndah and Mundubbera July 2003 - February 2007 showing details of fruit species collected.

Fruit name	No. of samples	Number infested	Fruit name	No. of samples	Number infested
Apple *Malus sylvestris*	7	4	Lion fruit *Carissa macrocarpa*	3	1
Brazilian cherry *Eugenia uniflora*	12	10	Litchi *Litchi chinensis*	4	0
Bush lemon *Citrus jambhiri*	21	5	✸ Loquat *Eriobotrya japonica*	45	23
Calomondin *Citrus mitis*	2	0	✸ Mandarin *Citrus reticulata*	276	26
Canistel *Poutoria campechiana*	7	3	✸ Mango *Mangifera indica*	53	17
Carambola *Averrhoa carambola*	21	0	✸ Mulberry *Morus nigra*	59	54
✸ Cherry guava *Psidium cattleanum*	28	23	Nectarine *Prunis persica* var. *nucipersica*	8	6
Crows apple *Owenia venosa*	1	1	✸ Orange *Citrus sinensis*	227	26
Custard apple *Annona squamosa*	4	2	Passionfruit *Passiflora edulis*	1	0
Edible fig *Ficus carica*	11	0	Pawpaw *Carica papaya*	2	0
Feijoa *Feijoa sellowiana*	1	1	Peach *Prunus persica*	32	15

Fruit name	No. of samples	Number infested	Fruit name	No. of samples	Number infested
Grape *Vitis vinifera*	3	0	Pear *Pyrus communis*	3	3
✸ Grapefruit *Citrus paradisi*	49	8	Persimmon *Diospyros kaki*	53	4
✸ Guava *Psidium guajava*	16	7	Plum *Prunus domestica*	2	2
Japoticaba *Myrecaria cauliflora*	1	0	Pomegranate *Punica granatum*	24	1
Kumquat *Fortunella japonica*	24	2	Pomelo *Citrus maxima*	1	0
✸ Lemon *Citrus limon*	150	8	Quince *Cydonia oblonga*	18	8
Lemonade fruit *Citrus sp.*	2	0	Tomato *Lycopersicon esculentum*	2	0
Lime *Citrus aurantifolia*	28	2			
Total number of samples		**1201**			
Number of infested samples		**262**			
% infestation of samples		**21.8%**			

✸ Most common host used as indicator fruits to evaluate AWM strategies (Details in Table 4).

By far the most common backyard host trees in Gayndah and Mundubbera were found to be citrus (177 trees - mandarins, oranges, lemons and grapefruit) and mangoes (453 trees) together accounting for 63% of fruit samples collected. The other common hosts known to be highly susceptible to fruit fly attack were cherry guava (16 trees), guava (20 trees), loquat (93 trees) and mulberry (129 trees) accounting collectively for 12.3% of fruit samples. More detailed results for these major hosts in town areas are given in Table 4. To gain a full picture of infestation patterns, for each host type, the numbers and percent of samples infested as well as the numbers of flies reared per kg of infested fruit (indicates host suitability) and numbers of flies per kg of fruit sampled (indicates likelihood of infestation) are shown. Results from surveys of non-commercial fruit undertaken in 1999 and 2002-2003 prior to any AWM strategies are included for comparison.

Table 4. Details of fruit assessment for major indicator hosts (marked ✸ in Table 3) in town areas of Gayndah and Mundubbera. Yearly results during the AWM program compared to results from fruit surveys in 1999 and 2002-2003 prior to implementation of AWM.

Fruit (No. of trees)	Year	No. of samples§	% samples infested	Flies/infested fruit	Flies/kg infested fruit	Flies/kg sampled fruit
Grapefruit	1999	5	60.00	4.04	17.50	10.32
(6)	2002-03	0	NA	NA	NA	NA
	2003	1	0.00	0.00	0.00	0.00
	2004	11	9.10	3.00	7.63	0.52
	2005	18	27.80	67.58	215.87	65.06
	2006	17	11.80	8.54	22.70	2.54
	2007	2	0.00	0.00	0.00	0.00
Lemon	1999	20	5.00	0.83	5.24	0.31
(37)	2002-03	4	0.00	0.00	0.00	0.00
	2003	2	0.00	0.00	0.00	0.00
	2004	55	1.82	1.64	6.38	0.23
	2005	54	5.56	0.41	4.99	0.31
	2006	32	12.50	1.97	21.58	3.53
	2007	7	0.00	0.00	0.00	0.00
Mandarin	1999	38	15.79	6.23	27.50	5.92
(85)	2002-03	8	25.00	1.54	10.68	2.97
	2003	5	60.00	3.38	58.97	41.24
	2004	109	9.17	1.12	9.61	0.86
	2005	83	8.40	4.59	40.65	3.79
	2006	65	7.70	4.01	43.80	3.43
	2007	14	7.10	3.33	43.71	1.98
Orange	1999	17	17.65	10.60	54.77	32.17
(49)	2002-03	2	0.00	0.00	0.00	0.00
	2003	15	53.30	3.20	21.60	11.11
	2004	74	12.20	3.27	19.45	2.18
	2005	75	10.70	4.08	27.30	2.62
	2006	50	0.00	0.00	0.00	0.00
	2007	13	7.70	1.63	11.76	0.87
Cherry Guava	1999	7	57.14	2.36	254.44	182.36
(16)	2002-03	3	100.00	2.92	707.72	707.72
	2003	1	0.00	0.00	0.00	0.00
	2004	6	83.30	6.60	1333.90	1194.91
	2005	9	77.80	4.35	552.13	448.86
	2006	4	75.00	7.43	1083.92	934.07
	2007	8	100.00	5.33	971.59	971.59
Guava	1999	4	75.00	13.00	200.90	184.14
(20)	2002-03	0	NA	NA	NA	NA
	2003	1	100.00	2.00	31.56	31.56
	2004	7	28.60	0.64	4.95	1.15
	2005	7	42.90	0.98	39.90	18.23
	2006	1	100.00	0.05	2.64	2.64
Loquat	1999	16	68.75	2.71	156.69	115.35
(93)	2002-03	18	94.44	1.82	155.56	150.56
	2004	21	38.10	3.19	324.53	157.83
	2005	18	50.00	3.49	421.46	213.85
	2006	6	100.00	13.87	933.34	933.34

Fruit (No. of trees)	Year	No. of samples§	% samples infested	Flies/infested fruit	Flies/kg infested fruit	Flies/kg sampled fruit
Mango (453)	1999	10	60.00	3.37	12.96	8.33
	2002-03	23	43.48	7.95	34.22	18.52
	2003	7	14.29	3.00	46.56	6.49
	2004	18	38.89	4.45	15.50	6.63
	2005	23	34.80	6.97	32.56	10.00
	2006	4	0.00	0.00	0.00	0.00
	2007	1	100.00	0.75	2.26	2.26
Mulberry (129)	1999	5	80.00	0.41	213.98	210.67
	2002-03	9	100.00	0.53	219.18	219.18
	2003	6	100.00	2.17	2136.51	2136.51
	2004	19	84.20	0.68	322.31	287.36
	2005	23	82.60	0.23	101.75	91.93
	2006	12	100.00	1.70	505.24	505.24

§ A sample consists of multiple pieces of fruit – see Materials and Methods

The numbers of trees of each host type recorded in the combined town areas do not necessarily correlate with availability of fruit for collection. Because of the serious drought situation in the Central Burnett during the project, fruiting for many backyard trees was very poor. Although some stonefruit (mainly peaches) were available for sampling in the first two years of the program, the prolonged drought conditions meant that there was almost no backyard stone fruit available for sampling later in the program. Hence stone fruit were not included as an indicator host in Table 4 although known to be highly susceptible to fruit fly atack.

Although many of the mango trees in town areas were very large trees, they were generally “common” mango varieties which produced poor crops particularly under the prolonged dry conditions. Many other backyard fruit trees were very small and poorly managed with limited fruit set. Furthermore, birds and possums often caused severe damage to backyard fruit and on several occasions during the project severe hail storms destroyed large quantities of fruit both in commercial orchards and in home gardens. On other occasions, when edible (almost fruit fly free) fruit was available, property owners were sometimes reluctant to hand it over for program assessment. Another factor which reduced the availability of fallen fruit for collection was the fact that numerous home owners followed the recommended practices of collecting and disposing of fallen fruit to reduce fly breeding. This was most evident during the mango fruiting season.

Overall infestation in town backyard fruit was reduced by 65% as a result of AWM strategies, however this effect was not consistent across all fruit types with some showing marked reduction in infestation and others not greatly affected. Furthermore, infestation levels in any one fruit type were often quite variable both before and after the implementation of AWM (Table 4). This is not unusual with fruit fly infestation in general but it may have been more evident due to the often small sample numbers which were available for some commodities. Infestation in the most common town hosts, citrus and mangoes, was generally reduced under AWM compared to infestation in 1999, but the effects of AWM on infestation in highly preferred hosts such as cherry guava, guava, loquat and mulberries was very variable. Guava was the only one of these known preferred hosts to show a marked decrease in infestation during the program (approximately 90% reduction from 1999 to 2005). Only one

guava sample was collected in 2006 and this sample was infested. Results for citrus in 2006-2007 compared to 1999 data showed infestation (flies per kg of sampled fruit) was reduced by 75% in grapefruit, 67% in mandarins and 97% in oranges. Yearly infestation levels in lemons were low and variable during the program. In mangoes, the AWM program resulted in 73% reduction in infestation per kg of sampled fruit from 1999 to 2007 and if results were compared with infestation in 2002-2003, the reduction in infestation was even greater.

Some apparently anomalous results in Table 4 can be accounted for by reference to the original sampling data. For instance, the high level of infestation in grapefruit in 2005 (65.06 flies/kg fruit) was because four out of the five infested samples in that year were over ripe, fallen fruit which were very heavily infested. The infestation level for the small number of samples of mandarins collected in 2003 was particularly high (41.24 flies/kg fruit). This was due to the fact that these fruit were collected late in 2003 and represented residual or second crop fruit which had hung on trees for several months thereby increasing the likelihood of infestation. Furthermore, at this early stage in the program, backyard baiting practices in town areas had been in place for only a short time and their effect on female fly numbers may have been minimal.

Comparison of the mean values for flies reared per kg of infested fruit for each host type across 2003-2007 also provided an indication of the potential significance of each host type in contributing to fly populations. The highly preferred hosts cherry guava (985 flies/kg infested fruit), loquat (559 flies/kg infested fruit), and mulberry (766 flies/kg infested fruit) gave rise to up to 80 times as many flies per kg of infested fruit as hosts of poorer suitability such as citrus (grapefruit – 82 flies/kg infested fruit, lemon – 11 flies/kg infested fruit, mandarin – 39 flies/kg infested fruit, orange – 20 flies/kg infested fruit).

The level of fruit fly parasitism in all fruit samples collected during the program was recorded. Of the 262 samples infested with fruit fly, 68 (25.9%) also contained fruit fly parasitoids. The actual numbers of parasitoids per sample were, however, relatively low. From the 18,444 fruit fly pupae recovered from these infested fruit, 1359 parasitoids emerged, representing 7.4% parasitism of fruit fly immature stages.

6.3.1 Infestation in second crop and residual commercial citrus

Results from the trial undertaken in late 2006 to assess potential control methods for infestation in end of season citrus were not conclusive (Table 5). In one orchard (2), continued baiting appeared to have reduced infestation but baiting was not as effective in orchard (4) and the orchard where no treatments were applied to the residual block did not show greatly increased infestation.

Fig. 10. High levels of fruit fly infestation in backyard host such as loquats, mulberries and stone fruit prior to AWM

Fig. 11. Edible backyard loquats after AWM was implemented.

Table 5. Effects of continued baiting and fruit fly parasitoid releases on infestation in end of season citrus.

Orchard	End of season treatment	Number of fruit	Wt of fruit (g)	Total flies present	Infestation flies/kg fruit
1	Released parasitoids	567	47576	567	13.4
2	Baiting continued	662	42685	662	3.0
3	Released parasitoids	332	39355	332	28.8
4	Baiting continued	633	30412	633	54.9
5	No baiting No parasitoids	653	44130	653	34.2

Assessment of other residual and second crop citrus [grapefruit from orchard (4) and oranges from orchard (3)] showed a high level of infestation in the grapefruit (123.2 flies/kg fruit) but much lower infestation in oranges (3.0 flies/kg fruit).

The percent of parasitism in the pupae recovered from all second crop and residual citrus fruit ranged from 0-4.9% for the released parasitoid (*Fopius arisanus*) to 0-9.3% for all parasitoids. These levels of parasitism were of the same order as natural parasitism found in sampled fruit (7.4%). The results from this small scale trial indicated that short term releases of parasitoids did not significantly enhance parasitism and had little effect on reducing fruit fly numbers in residual citrus in commercial orchards.

6.4 Grower survey 2005

The written questionnaire sent to all growers in November 2005 provided valuable feedback on the effectiveness of the AWM strategies at that stage in the program. Of the 25 growers who responded, all had used baiting and MAT in the 2005 season and 5 of the 24 had used insecticide cover sprays as well at times of high pressure. When asked to comment on the effects of AWM on fruit fly control in their own orchards, 46% of growers (11/24) reported significant improvement, 50% (12/24) reported minor improvement and the remaining 4% (1/24) claimed no improvement. With respect to the future of the AWM program, 100% of respondents considered it worth continuing and 75% were prepared to contribute funding towards an ongoing program.

Comments from growers on the effectiveness of the AWM program were generally favourable (as follows).

- Reduced overall fruit fly populations.
- Less pressure on baiting to achieve control.
- Timing of bait application was not so important.
- Observed higher fly pressure in orchards outside the AWM zone.

- No fruit fly infestation observed in citrus with baiting once per week.
- Lower fruit fly activity observed in harvest periods.
- No additional cover sprays required in Murcotts to ensure protection (frequently required prior to AWM because Murcotts are inherently highly susceptible and they mature late in the season when fly pressure is naturally increasing).
- Growers have a better awareness of fruit fly (eg. in table grapes)
- Less pressure on Imperial mandarins at beginning of season (March).
- Baiting able to be reduced from twice per week to once per week.
- Lower trap catches noted.
- Improved control of early infestation in grapes.
- Good control in citrus and mangoes across all varieties.
- Good control in late season Murcotts - able to delay harvesting into October (which is normally a time of high fly pressure).
- One grower reported a minor improvement in citrus but still had some problems in grapes.

7 DISCUSSION

7.1 Effectiveness of AWM Program

This project has demonstrated for the first time in Queensland that a coordinated approach to area wide management of fruit fly can be very effective in reducing pest pressure in a major horticultural production area where Queensland fruit fly is endemic. The acknowledged requirements for successful AWM programs as summarised by Jorgensen (2002), Lindquist (2000) and Tan (2000)were taken into account in developing and implementing this program. The project was based on in-depth knowledge of fruit fly activity in the target area which contributed significantly to the successful implementation of control measures. Natural climatic and geographic conditions as well as the existing applied control measures were already providing effective fruit fly control in the winter citrus crop prior to the commencement of AWM. However, no previous attempt had been made to improve fruit fly control in summer host crops such as table grapes and mangoes and no treatments had ever been applied in the town areas of Gayndah and Mundubbera which were known to harbour large numbers of heavily infested host trees in private backyards.

The implementation of year round MAT in commercial orchards, improved baiting in non-citrus summer crops and application of baiting and MAT to town areas of Gayndah and Mundubbera have had a very significant impact, reducing fly populations by 95% based on peak male lure trap catches. Both baiting and MAT are known to work most effectively when used on an area wide basis which again met one of the prerequisites for an effective AWM program. However, the problem of interpreting male trap catches in the presence of competing MAT devices and in the absence of an effective female trap is well recognised. Hence other quantitative and qualitative methods have been used to evaluate the effectiveness of the program eg. extensive fruit collection, and grower and consultant feedback. The greatly reduced

trap catches at numerous untreated indicator sites clearly showed that AWM strategies were effective in reducing fly numbers across the entire district.

As explained previously, infestation levels in commercial citrus were shown in previous research to be extremely low (less than 0.029-0.047%) and so evaluating the impact of AWM by further assessment of infestation in this commercial fruit was not an economically viable option for this project. Monitoring infestation levels in backyard fruit in town areas surrounded by commercial orchards was a more manageable and useful evaluation tool. Results clearly showed the beneficial effects of AWM. Overall infestation in backyard fruit (based on numbers of infested samples) was reduced by 65% (60.8% infestation prior to AWM to 21.8% infestation during the program). However, the effects of AWM treatments on infestation levels varied for different host types. There was a 72-94% reduction in infestation in citrus and mangoes by the end of the project, but there was little effect on infestation in the highly susceptible backyard hosts such as loquats, cherry guava and mulberries which varied from year to year. However, infestation in another highly preferred host, guava, showed a marked decrease during the program. The precise reasons for the different effects on different hosts are not known. It may simply reflect the higher suitability of some hosts for oviposition and immature development with reduced populations of flies continuing to seek out these hosts in preference to other available hosts such as citrus and mangoes. These results also suggest that flies may be overwintering in town citrus and bait treatments on backyard trees may be having a very targeted effect on female flies, thereby greatly reducing the likelihood of infestation in this host.

Comparison of the mean number of flies/kg reared from all types of town backyard citrus (7 flies/kg) to the mean number of flies/kg reared from all residual/second crop citrus in commercial orchards (37 flies/kg) indicated that the latter may be a much more significant source of summer flies than was previously thought. Some baiting and parasitoid releases took place in five of the seven orchard blocks in this study but fruit fly infestation levels in all but two blocks were still higher than that in town backyard citrus. When the extent of residual and second crop citrus that is likely to be available for infestation across approximately 70 orchards in the district is taken into account, it is evident that more intensive efforts to minimise this end of citrus season infestation could further enhance the effectiveness of AWM.

One option would be to remove all residual and second crop late season citrus fruit. It is unlikely that this would be economically feasible for large scale commercial growers. The alternative would be to continue to apply bait sprays to harvested citrus blocks until there is no longer any fruit available for fruit fly breeding. This was recommended to growers in the last two years of the project but was generally only implemented by citrus growers who were experiencing fly damage in nearby blocks of summer maturing table grapes. A more focused district wide approach with all citrus growers treating residual/second crop fruit could provide additional benefits in further reducing fly numbers leading into summer.

All of the trapping and fruit collection data clearly showed that Queensland fruit fly was the major species of concern in the Central Burnett. The field trial to test the effectiveness of released fruit fly parasitoids in reducing fly numbers at the end of the citrus season was not conclusive. The percentage of other non-commercial fruit samples which gave rise to fruit fly parasitoids was relatively high (25.9%) indicating

a significant spread of natural biological control agents for fruit fly in the town areas. However, the numbers of parasitoids emerging from any fruit fly infested samples were low, accounting for only 7.4% of recovered pupae. The results indicated that neither natural parasitism in the area nor small scale release of parasitoids was likely to be having a significant effect in reducing fruit fly populations. The expense of producing large numbers of parasitoids for area wide inundative releases prevented further investigation.

7.2 Project management

The management approach adopted for this project was based on the establishment of a management body representing all stakeholders (Lindquist 2000). The Central Burnett Area Wide Management Committee comprising researchers, crop consultants, local government representatives and industry stakeholders effectively filled this role. The scientific expertise of the DPI&F team was complemented by the high level of expertise and local district and crop knowledge of the participating crop consultants from the Central Burnett. The funding mechanism approved by HAL worked particularly well with growers contributing a total of $613,454 as voluntary contributions over the duration of the project. The numbers of growers contributing the value of their fruit fly control materials were 47 in 2003-2004, 39 in 2004-2005, and 36 in 2005-2006. The effects of the drought and a down turn in citrus prices caused numerous orchards to be sold during the course of the project which adversely affected grower contributions in the second and third years of the program. However, this did not impact significantly on AWM program activities.

7.2.1 Operational activities

There were no major problems with operational activities during this project. Both Gayndah and Mundubbera Shire Councils strongly supported the program and contributed by supervising staff employed to undertake town monitoring and treatments. At the beginning of the project, the council staff responsible for AWM activities were also involved in other council work. This lead to some issues about work priorities but this was resolved when staff were employed to work on the AWM program only and a designated vehicle was assigned to and paid for by the project.

7.2.2 Community engagement

The research team and the management committee put a great deal of effort into community engagement activities particularly in the early stages of the program (details in Section 8 of this report). The adoption of a program identity (The Fruit Fly Force) assisted in attracting community attention and enhanced community ownership of the program. All communication strategies appeared to be positively received by the community. The displays organised by the project team at the local shows and at the Gayndah Orange Festival were particularly worthwhile in explaining the value of the program to the whole district. The fact that 89% of town property owners were willing to participate in the program in some way was indicative of the generally high level of support form the Central Burnett community. There were no complaints about any town activities during the program and no negative publicity in the local media. Presentations by the research team and consultants to the two Shire Councils and feedback to the councils through the Environmental Health Officer who was a member of the CBAWM Committee ensured that the local government authorities were well informed about progress of the program.

7.3 Market access implications

The successful implementation of fruit fly AWM in the Central Burnett district has demonstrated that an ongoing AWM program could provide an additional layer of phytosanitary security for fruit fly host commodities grown in this area. This will be particularly relevant to the development of any systems approach market access protocols for citrus and table grapes in the future. Such systems approaches will be based on a combination of natural and applied risk reduction measures for fruit fly such as the current domestic market access protocol for Central Burnett citrus accepted by Victoria under the Interstate Certification Assurance (ICA) scheme (ie. ICA-28). An ongoing AWM program would provide an additional measure of fruit fly control which, hopefully, will lead to other states accepting ICA-28. This will be critical for maintaining domestic markets for Central Burnett citrus if dimethoate postharvest treatments are restricted, as expected, in the near future. The alternative 16 day cold treatments which are currently permitted for interstate market access are not practical or economically feasible for Queensland citrus growers.

At this stage it is not known what regulatory requirements, such as ongoing monitoring or fruit assessment, may be required by domestic or international trading partners for AWM to be incorporated into market access protocols. The research team will continue to consult with the Domestic Quarantine and Market Access Working Group and with Biosecurity Australia on this issue.

7.4 Economic Analysis

The Benefit Cost Analysis of the project (Executive Summary in Section 9) showed the Net Present Value of the AWM project and the ongoing self-funded AWM program over the next ten years was found to be $5.2m. The Internal Rate of Return was 18% and the Benefit Cost Ratio was 2.27:1. This study was based entirely on the benefits that AWM would provide in alternative systems approach market access protocols if dimethoate postharvest treatments are lost for interstate market access for citrus. The potential benefits from the program are substantially greater than this, indicating that the overall value of the program to all stakeholders would be significantly higher than that calculated in this study. This economic analysis will provide useful information for other horticultural industries and production areas considering the potential economic value of implementing similar AWM programs.

7.5 Ongoing AWM in Central Burnett

In the grower survey carried out during this project, 100% of respondents considered it was worth continuing the AWM program beyond the existing HAL funded project. The CBAWM Committee has acted on this and has begun collecting funds from growers for an ongoing, industry funded program commencing in June 2007. The existing management structure for the program will be maintained and the DPI&F research team will continue to have a supervisory role during the next four years as part of a small ongoing HAL funded project CT06046 - “Area wide management of fruit fly - Central Burnett Phase 2”. An important component of the Phase 2 project will be consulting with regulatory authorities to determine what procedures will need to be implemented for AWM to be recognised as a component in systems approach market access protocols.

8 COMMUNICATION AND TECHNOLOGY TRANSFER

8.1 Existing communication linkages in the Central Burnett

Prior to commencement of the AWM project in the Central Burnett, strong communication linkages established over more than two decades of collaborative research projects, already existed between the research team, citrus growers and crop consultants. The CBHC and Queensland Citrus Growers had contributed funding to many DPI&F projects related to citrus industry issues such as IPM, fruit fly control, market access, plant breeding, production and fruit quality. Many growers have been involved in experimental trials and crop consultants have provided on-going assistance in research activities. The research team members were already well known to the Central Burnett citrus industry and to individual growers. Citrus growers who also grew grapes were already part of this communication network, but linkages with commercial growers of grapes only were not as strong. These existing communication networks provided a sound basis for implementing an AWM fruit fly control scheme.

8.2 Communication aims in the AWM Project

The primary aims of communication strategies in the AWM project were as follows:

- To ensure effective management of the program through a committee of diverse stakeholders working in close collaboration with the research team.
- To collect financial contributions from individual growers each year to provide the Voluntary Contribution for HAL matched funding to maintain the project as planned.
- To provide information to all commercial growers on the recommended AWM control methods.
- To specifically target non-citrus commercial growers (mainly table grapes) to improve on-farm management of fruit fly.
- To provide regular updates to all Central Burnett stakeholders on project activities and progress of the AWM program.
- To engage town communities to support the program and to give permission for AWM activities to be undertaken on private properties.
- To share the concept and progress of the AWM program with other horticulture industries which could benefit from similar programs.
- To exchange scientific information on AWM with research colleagues within Australia and from overseas.
- To maintain ongoing communication with domestic and international biosecurity authorities to ensure that project goals and outcomes were relevant to market access issues including international phytosanitary standards on areas of low pest prevalence and on systems approaches now in the developmental stages.
- To hold a national workshop on AWM to communicate results of the project and to share information about other AWM activities with research and regulatory personnel from across Australia.
- To promote the project as a coordinated research/industry/community initiative to provide benefits to horticultural industries and to act as a role

model for other endemic fruit fly areas where AWM could enhance fruit fly control, crop protection and market access opportunities.

8.3 Communication strategies

The strategies employed to address the above communication aims were as follows:

8.3.1 Project management

- The CBAWM Committee, which consisted of DPI&F researchers and representatives from CBHC, Gayndah and Mundubbera citrus growers, non-citrus growers, crop consultants, Gayndah and Mundubbera shire councils, facilitated communication to all of these stakeholder groups.
- The CBAWM Committee met at least twice per year in addition to the Annual General Meeting. Minutes of meetings were circulated to all Committee members.
- The DPI&F Project Leader and the Chair of the CBAWM Committee corresponded regularly with other committee members by email and teleconferencing.
- The DPI&F Project Leader was responsible for all communication with and formal reporting to HAL.
- The Shire Council representative was responsible for supervising local communication (eg. letter box drops and mail outs) to the town communities, raising council issues with the CBAWM Committee and for reporting back to the Shire Councils on program activities.
- The Project Leader, in consultation with committee members, was responsible for written communications which were mailed to all growers by the Committee bookkeeper.
- The bookkeeper was responsible for providing financial reports at each committee meeting, communicating with growers in relation to financial contributions and reimbursements for costs of fruit fly control materials, and arranging for the CBHC Inc financial records to be examined each year by an external auditor.

8.3.2 Grower communication and education

Effective communication between the CBAWM Committee and growers to ensure a high level of commitment to financial contributions and implementation of recommended fruit fly controls in orchards included the following:

- Mail outs were sent to all growers in the district explaining AWM activities, encouraging financial contributions, and providing program updates.
- Numerous grower meetings were held prior to and during the project to explain AWM strategies and report on progress.
- Several meetings specifically targeting grape growers were held to ensure that the recommended control practices were thoroughly understood.
- Local crop consultants maintained close contact with growers they serviced, provided advice on recommended AWM strategies, encouraged growers to make financial contributions to fund the project, and provided direct feedback on fruit fly control issues to the CBAWM Committee.

8.3.3 Community engagement

- Information on the CBAWM scheme was provided to the community prior to and during the project in the form of shop posters (Appendix 1) mail outs to all ratepayers and letterbox drops in town areas (Appendix 2).
- Pictorial instructions about how town property owners could participate were distributed at the beginning of the project (Appendix 4)
- All mail out information in town areas was printed on orange (mandarin) coloured paper as another identifying factor in the project.
- Forms recording individual property owner's willingness to be involved in the program and what activities they would permit on their properties were mailed or delivered to all properties in the town areas of Gayndah and Mundubbera (Appendix 3). No activities were undertaken on private property until permission forms had been signed by the property owner.
- The use of "The Fruit Fly Force" name and logo on promotional material, on T-shirts for Committee members and council operators, and on the council vehicle used for town activities was extremely useful in generating and maintaining community awareness of the program.
- A promotional package including handouts, posters, project update charts and displays of live fruit flies, larvae and rotting fruit was developed by the research team and used extensively in district activities eg. posters in shop windows, displays at the Mundubbera Show and Gayndah Orange Festival, information stall at the local markets. The use of live insects in displays proved to be particularly beneficial as many member of the community thought *Drosophila* were "fruit flies" and had no knowledge of tephritid pest species.
- Research team members and the local crop consultants delivered presentations to both the Gayndah and Mundubbera Shire Councils on several occasions to provide information on the project.
- The crop consultants addressed school students and spoke at the local garden show about the aims and benefits of the program.
- Numerous articles have been published in Central Burnett newspapers and the research team and local consultants have been interviewed on local radio about the AWM program.

Fig. 12. Project Leader Annice Lloyd, with Brian Gallagher (crop consultant) and Neil Giddins (Gayndah Shire Council) on the Fruit Fly Force stall at the Gayndah Orange Festival in 2005.

Fig. 13. Team members Neil Giddins and Kristy Neibling (left) from Gayndah Shire Council and Ed Hamacek and Thelma Peek (right) from DPI&F with the Fruit Fly Force display at the Mundubbera Show in 2004.

Fig. 14. Display of live fruit flies ovipositing into fruit, jumping larvae in laboratory rearing medium and infested mandarins used to enhance community engagement in the AWM program in the Central Burnett. Photos from the Gayndah Orange Festival display 2005.

8.3.4 Communication with quarantine authorities

- DPI&F Market Access Team in conjunction with the DPI&F Asian Markets for Horticulture Initiative hold twice yearly meetings with representatives from Biosecurity Australia to discuss market access issues. Regular updates on the progress of the AWM program have been provided at these meetings.
- Ongoing communication was maintained with the DPI&F representative on the Domestic Quarantine and Market Access Working Group to facilitate inclusion of AWM as a component in domestic market access protocols.
- At a meeting with New Zealand Biosecurity representatives from the Ministry of Agriculture and Fisheries in Brisbane, May 2007, the concept of AWM as a component in systems approaches to achieving biosecurity for fruit fly host commodities was discussed.

8.3.5 Wider industry communication

Updates on the progress of the CBAWM program have been communicated to a wide range of horticulture industry stakeholders using a variety of communication methods as follows.

- Articles in industry journals eg. Citrus News, Fruit and Vegetable News, The Custard Apple Newsletter, Citrus Insight, Good Fruit and Vegetables, Australian Citrus Growers Season Update, HAL Across Industry Report.

- Articles in other written media eg. Myrmecia – News Bulletin of the Australian Entomological Society, DPI&F Connections, Brisbane Courier Mail, Central Burnett Times.

- Presentations at industry conferences and meetings which were specifically on the program or included an overview of the program:
  - Australian Citrus Growers Conference, 2003
  - Australian Organics Conference, Cairns, 2003
  - Australian Custard Apple Growers Conference, Ballina, 2003
  - Citrus Postharvest Workshop, Adelaide, 2003
  - Grape grower meeting, St George, 2003
  - Queensland Citrus Growers meetings, Gayndah, 2003
  - Queensland Citrus Growers meetings, Gayndah, 2004
  - Grape Connect Forum, Mundubbera, 2004
  - Temperate fruit grower meeting, Applethorpe, 2004
  - Australian Citrus Growers Conference, Bargara, 2005
  - Australian Mango Industry Association Conference, Townsville, 2005
  - Grape Connect Meeting, Mooloolaba, February 2006
  - Presentation at Growcom – DPI&F Industry forum on dimethoate and fenthion issues, Brisbane, December 2006

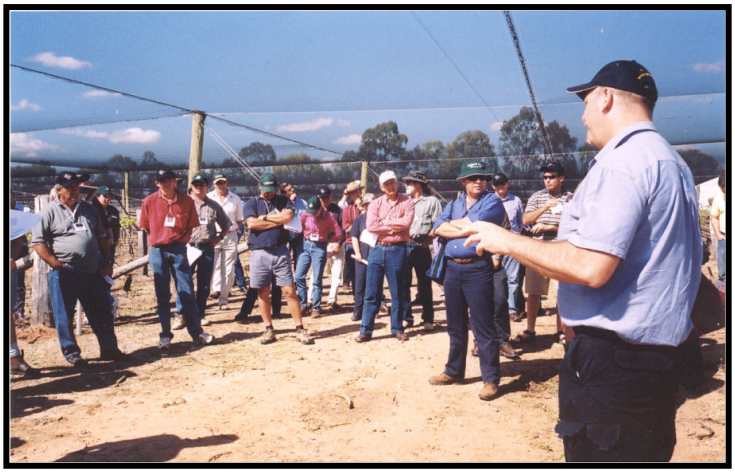

Fig. 15. Research team member Ed Hamacek advising grape growers about fruit fly control at a Grape Connect Forum at Mundubbera in 2004.

8.3.6 Funding body communication

- Milestone reports have been provided to HAL as required and yearly progress reports have been provided for cross industry publications.
- Project overview presented to HAL National Fruit Fly Meeting, Sydney, September 2005

- Project overview presented to HAL Working Group on Market Access Research and Development, Brisbane, December 2006

8.3.7 Technology transfer and scientific communication

- Exchange of information with researchers undertaking a fruit fly AWM program in Hawaii and visit to Hawaii by two research team members (see section 8.4 for more detail)
- Display at International Congress of Entomology, Brisbane, August 2004
- Presentation on AWM to horticultural delegation from Thailand, January 2005
- A national workshop in the Central Burnett in May 2006 to present the outcomes of the project to HAL, interstate researchers, quarantine officers and industry representatives.
- Two new industry-HAL funded projects commenced by DPI&F researchers in 2006 both of which have a component to collect data on the potential for AWM in different commodities in different horticultural production areas viz. pome fruit in the Granite Belt and tomatoes and capsicums in the Bowen-Gumlu area. Both projects also aim to evaluate systems approaches as alternatives to dimethoate postharvest treatments for interstate trade. The experience gained and the methodology used in the Central Burnett AWM project is contributing to both of these new projects.

8.4 Hawaiian collaboration and study tour

During the XXII International Congress of Entomology held in Brisbane in August 2004, the AWM project team met with Hawaiian researchers involved the Hawaii Fruit Fly Area Wide Pest Management Program. Prior to 2001, Hawaii had very limited capability to control fruit flies due to a lack of registered insecticides for incorporation into protein bait sprays. The registration of the Dow product GF-120 (registered in Australia as Naturalure Fruit Fly Bait Concentrate™) allowed Hawaiian researchers to develop and encourage the use of fruit fly control strategies on an area wide basis. This program has had a significant impact on the productivity and sustainability of the horticulture industry in Hawaii.

The AWM project team and visiting Hawaiian researchers exchanged information about their respective AWM programs. These discussions resulted in an invitation to the Central Burnett team to present papers on the progress of the project at the Fourth Annual Meeting and Review of the Hawaii Fruit Fly Area Wide Pest Management Program in April 2005. Horticulture Australia approved funding through the Central Burnett Area Wide Management project for two representatives of the committee, Ed Hamacek, DPI&F and Dan Papacek, Bugs for Bugs to attend.

The Hawaiian trip provided an excellent opportunity to exchange information on AWM programs. The meeting was attended by Hawaiian researchers and growers, representatives of Dow Agrosciences from Australia, Taiwan and the USA, as well as scientists and representatives from the South Pacific Commission, Northern Marianas, Australia, California, and Washington. It provided an opportunity to present information on the area wide fruit fly management program in the Central Burnett and its integration with current IPM systems for citrus. The associated informal meetings and study tour provided a means to strengthen existing collaborative research links

and to initiate discussions to expand links within the region. Opportunities arising from these meetings included possible collaboration between Hawaiian and Australian scientists to further develop and test improved fruit fly lures, laboratory rearing techniques and field control methods. A full report on the Hawaiian trip was provided to HAL in June 2005.

8.5 National AWM Workshop

As a component of the technology transfer activities in this project, a two day National Workshop on Area Wide Management of Fruit Flies in Endemic Areas was held in Gayndah in May 2006.

8.5.1 Workshop aims

- To share fruit fly AWM experiences in endemic fruit fly areas with other researchers, identifying positive and negative issues.
- To explore mechanisms for implementing and funding AWM programs.
- To examine the potential for AWM programs in endemic areas in market access protocols.
- To provide a Workshop Report summarising the above issues as a reference guide for future AWM programs in endemic fruit fly areas.

8.5.2 Workshop participants

Twenty-one participants attended with representatives from a variety of fruit fly management programs in endemic areas: NSW (Orange & Narromine), WA (Medfly), Victoria (north eastern area) and Torres Strait as well as from the three current DPI&F fruit fly management projects (Central Burnett, Granite Belt and Bowen). Three Central Burnett crop consultants, the local shire council environmental health officer, Central Burnett growers and representatives from HAL, DPI&F Biosecurity and Queensland Citrus Growers also participated.

8.5.3 Workshop activities

The workshop program included presentations and discussions on a wide range of fruit fly management programs with the positive and negative issues being shared in an attempt to provide guidelines for future programs. The diversity of endemic fruit fly areas in Australia and the need for programs targeted to meet locational, commodity specific and social issues was highlighted. The workshop program also included a district tour and a visit to the Bugs for Bugs Insectary which produces the beneficial insects used in the well established IPM program in Central Burnett citrus.

Fig. 16. Participants at the AWM Workshop in May 2006 during an on-farm inspection to view fruit fly control procedures and spraying equipment.

8.5.4 Workshop conclusions

- The Workshop highlighted the diverse range of fruit fly management programs in Australia that can be classified as Area Wide Management.
- All AWM programs, current or proposed, have in common the goal of reducing fruit fly numbers on a year round basis using whatever control strategies are appropriate, affordable and economically sustainable for the target area.
- The desired level of fruit fly control and market access opportunities, based on AWM, were very specific to each area.
- In Narromine NSW, the aim was to demonstrate property freedom from fruit fly in a low pest prevalence area for navel oranges during winter.
- In Orange NSW, the aim was to demonstrate climatic freedom from fruit fly for cherries during the harvest period, from November to mid-January.
- For Medfly in WA, proposed programs focused on demonstrating areas of low pest prevalence during winter months and utilising protein baiting and SIT in areas with higher populations.
- In the Central Burnett in Queensland, the AWM program aimed to reduce fly pressure across the entire district on a year round basis so that the winter citrus crop as well as the summer mango and table grape crops would have an additional level of security, which could be used in negotiating market access to fruit fly sensitive markets.
- The two projects on Queensland fruit fly in the Granite Belt and in the Bowen area had common goals - to obtain comprehensive district wide survey data to determine if AWM could deliver specific benefits and to determine if high levels of field control could remove the need for dimethoate postharvest treatments currently required for interstate market access.

- The fruit fly suppression program in north eastern Victoria included many control methods and promotional activities which are also applicable to other programs.
- The NAQS program in Torres Strait clearly demonstrated how operational and community engagement activities must be targeted to meet the needs of all stakeholders in a program.

Overall, the exchange of information was very valuable, common issues were identified, some "dos" and "don'ts" in AWM were shared and participants came away with a much better understanding of the complexity of fruit fly AWM issues.
A 53 page report on the workshop including copies of all presentations and summaries of issues discussed was prepared by the project team, submitted to HAL and circulated to all participants. The report was also made available to others interested in AWM in endemic fruit fly areas.

8.6 Awards

The CBAWM project was nominated for the 2004 Queensland Premier's Award for Excellence in Public Sector Management in the category of "Engaging Communities". As one of a small group of finalists in each category, the project team was invited to attend the presentation ceremony with the Premier of Queensland and other high ranking government officials. A professionally prepared overview of the project was presented on the night but unfortunately the project was not successful in winning the award in this category.

9 ECONOMIC ANALYSIS

9.1 Aim

Although not originally included as part of HAL Project AH03002, an economic analysis of the completed project and of the proposed Phase 2 of the AWM program has been undertaken by DPI&F officers Mary-Ann Franco-Dixon and Sarah Chambers from Industry Development, Innovation and Biosecurity Investment, Department of Primary Industries and Fisheries. The full report on the economic analysis has been submitted to HAL as a separate document and the Executive Summary only is included here.

9.2 Result

9.2.1 Executive summary

The Central Burnett district is the major citrus production area in Queensland contributing about 80 per cent of Queensland's citrus crop. The Queensland fruit fly (*Bactrocera tryoni*) which is the most widespread and damaging of Australian pest fruit fly species is also endemic to the Central Burnett area.

Queensland fruit fly is the most significant quarantine market access barrier for Central Burnett citrus. In a recently completed project (HAL Project AH03002), funded by Central Burnett growers and Horticulture Australia Ltd., researchers from the Queensland Department of Primary Industries and Fisheries have implemented an area wide management (AWM) program for fruit fly in the Central Burnett district. The aims of the project were to improve fruit fly management in all host commodities grown in the district and to use AWM as a component in systems approach protocols to maintain and enhance market access opportunities for all growers.

Queensland's domestic trade in citrus is worth $15 million per year. To access domestic markets in South Australia, Western Australia and Tasmania, Central Burnett citrus must undergo postharvest chemical treatment with dimethoate or a two week long cold disinfestation treatment which is not economically viable for domestic markets. Victoria is currently the only state which will accept an alternative treatment under the Interstate Certification Assurance (ICA) Scheme. This alternative protocol (ICA-28) based on preharvest baiting and postharvest inspection enables producers to take a systems approach to fruit fly control and removes the need for postharvest use of dimethoate.

It is a high priority for the Queensland citrus industry to gain wider acceptance of this non-dimethoate market access protocol. The Australian Pesticides and Veterinary Medicines Authority (APVMA) is currently reviewing all uses of dimethoate based on toxicology concerns about the acute daily reference dose for this chemical. The results of this review, due for release in 2008, are likely to severely restrict many current uses of dimethoate. Loss of dimethoate postharvest treatments for citrus will cause loss of market access to South Australia, Western Australia and Tasmania. Acceptance of ICA-28 by these states would ensure maintenance of these markets. The likelihood of wider acceptance of this protocol is significantly enhanced by establishment of an AWM program. The AWM program provides an additional level

of quarantine security for Central Burnett growers, complementing the already high level of on-farm control and further reducing the risk of fruit fly infestation in the packed product.

The first phase of the AWM program in the Central Burnett was completed in May 2007 and the program is now entering its second phase which will be funded entirely by Central Burnett growers. This study is a benefit-cost analysis on both phases of the program. The study focuses on the benefits to Central Burnett producers using the state contingency approach, considering the probabilities of the outcomes for both the domestic market access issues and the APVMA decisions, with and without AWM.

This study has found that the AWM program has the potential to dramatically reduce the negative impact of the removal of dimethoate on the citrus industry. Without AWM, the removal of dimethoate by the APVMA would cost the Central Burnett citrus industry around $4.5 million due to the loss of access to domestic markets. With AWM, the probability of a worst case scenario decreases and the same decision on dimethoate would cause losses of $2.3 million. Although the AWM program will not prevent the removal of dimethoate, it will reduce the negative impact on the industry by $2.1 million per year. At a discount rate of 5 percent, the Net Present Value of the AWM project and the ongoing self funded AWM program over 10 years was found to be $5.2 million, with an Internal Rate of Return of 18%, and a Benefit Cost Ratio of 2.27:1. These results indicate that the project is of net benefit to Central Burnett producers and the investment costs can be justified.

The AWM program in the Central Burnett also provides benefits to other commercial fruit fly host crops such as table grapes, mangoes and stone fruit grown in the district. An additional benefit to the town communities is the availability of edible home grown fruit and fruit fly host vegetables due to greatly reduced infestation in backyard hosts. This study has shown that the program is cost efficient when the benefits to commercial citrus producers only are evaluated. It can therefore be assumed that the overall value of this program to all stakeholders would be significantly higher than that calculated in this study.

10 RECOMMENDATIONS

It is recommended that:

1. AWM for fruit fly should continue to be implemented in the Central Burnett.
The success of the AWM program and the grower survey which indicated a high level of support for an ongoing program has led to the implementation of Phase 2 of the program commencing in June 2007. This program will be funded by voluntary contributions from Central Burnett growers. A small component of the contributed funds will be used for an ongoing HAL funded project (CT06046) which will enable the DPI&F team to continue in a coordinating and supervisory role in the ongoing program.

2. AWM should be incorporated into systems approach market access protocols.
Consultation between the research team and both domestic and international biosecurity authorities should be maintained to ensure that procedures can be implemented which will allow AWM to be incorporated into systems approach protocols for market access. Results of programs such as this also provide useful information for Biosecurity Australia representatives to contribute to the development of international standards for systems approaches and for recognition and maintenance of areas of low pest prevalence.

3. The Central Burnett AWM Program can provide a model for other AWM programs to follow.
The management and operational procedures used in the Central Burnett provide a model for other fruit fly endemic areas to follow when implementing AWM programs. However, it should be emphasised that AWM should not be attempted without an in-depth understanding of fruit fly activity, seasonal abundance and host relationships in any particular target area. Furthermore, the practicality, the scientific justification and the economic feasibility of implementing AWM must be carefully assessed before embarking on any programs which involve treatments in non-commercial production situations.

4. Ecological research to underpin AWM strategies for fruit fly should be undertaken.
There is a need for basic fruit fly ecological research to optimise the use of the AWM strategies (protein baiting and MAT) which have been implemented in this project. Relatively little is known about overwintering behaviour of Queensland fruit fly in sub-tropical areas, the effects of temperature on lure and bait responses and the effects of crop architecture on infestation. An improved knowledge of these issues would greatly enhance the implementation of combined field control strategies which are likely to be necessary in the future to achieve the very high levels of crop protection required to meet market access requirements based on AWM and systems approaches.

11 ACKNOWLEDGEMENTS

Contributions to this project from the following are gratefully acknowledged. Names of individual contributors are shown in Project Details.

- Market Access Team members in DPI&F
- Central Burnett Area Wide Management Committee
- Gayndah and Mundubbera Fruit Grower Associations
- Central Burnett growers
- Central Burnett crop consultants
- Queensland Citrus Growers
- Gayndah and Mundubbera Shire Councils
- Council operators responsible for town treatments and monitoring
- Town communities of Gayndah and Mundubbera
- Domestic and export regulatory authorities
- Horticulture Australia and AusHort

The research team would like to make particular mention of our former DPI&F colleague, Dan Smith, who passed away in late 2004. Dan was a highly respected entomologist who had worked with the citrus industry in the Central Burnett for many years. He also made a very significant contribution to our fruit fly research, was a member of the original AWM Committee and actively participated in planning and implementing this program. His friendship and expertise has been sorely missed by members of the AWM Committee.

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13 APPENDICES

APPENDIX 1 Area Wide Management Poster

FRUITFLY
FORCE

Area Wide Management Program for Fruit Flies in the Central Burnett

To all property owners in the town areas of Gayndah and Mundubbera -

- *We need your help*
- *to control*
- *this damaging insect pest.*

For further information about how you can participate in this program, please read the orange Fruit Fly Force flyers in your letter box or contact any of the following:

Fruit Fly Force Chairman: Allen Jenkin 07 41654670
Shire Council Representative: Russell Lyons 07 4161 1377, 07 4165 3909
Crop Consultants: Dan Papacek 07 4165 4663
Brian Gallagher 07 4161 2223
Malcolm Wallis 07 4165 3333
QDPI Project Leader: Dr Annice Lloyd 07 3896 9366
QDPI Extension Officer: Garry Fullelove 07 4936 0236

Supported by:

- Central Burnett Horticulture Council Inc.
- Local Crop consultants
- Central Burnett horticultural producers
- Horticulture Australia Ltd.
- Gayndah and Mundubbera Shire Councils
- Queensland Department of Primary Industries

APPENDIX 2 Fruit Fly Force Flyer

CENTRAL BURNETT

April 2003

FRUIT FLY FORCE

➡ A new Area-Wide Management Program for Fruit Flies in the Central Burnett.

Initiated and managed by: Central Burnett Area Wide Management Committee as a sub-committee of the Central Burnett Horticultural Committee.

Involving:

- ◆ All horticultural producers (citrus and other crops)
- ◆ Town communities in Gayndah and Mundubbera
- ◆ Local crop consultants
- ◆ Shire Councils in Gayndah and Mundubbera
- ◆ Queensland Department of Primary Industry researchers

Background:

- Fruit flies are a major pest for all growers in the Central Burnett.
- Control measures are routinely applied to fruit crops to ensure high quality, fruit fly free produce.
- However, fruit fly control on an area-wide basis has not previously been attempted.
- No coordinated control measures are currently applied in town areas.
- Untreated backyard trees (such as citrus, mangoes, loquats, stone fruit, mulberries, cherry guavas) provide ideal breeding sites for fruit fly populations in town areas.

➡ ➡ ➡ Proposed fruit fly control methods commencing July 2003

In orchards:

- Close liaison with commercial growers will aim to achieve best practice fruit fly control in orchards.

In town areas of Gayndah and Mundubbera:

- Property owners will be asked to allow Council employees to enter their yards to apply fruit fly treatments, to install fruit fly traps and to sample backyard fruit.
- Householders will also be asked to assist the program by disposing of fallen and rotting fruit from trees on their properties to minimise fruit fly breeding.

Town fruit fly treatments will involve:

- Seasonal application of protein bait spots to the foliage of fruiting host trees. This is the same fruit fly control method that is currently practised in almost all citrus orchards.
- Installation of one fruit fly control cup in a tree on every town property. The cups contain wicks dosed with the male fruit fly attractant (cue-lure) and a small amount of insecticide. They are designed to reduce the male fruit fly population to a level low enough to severely limit fruit fly breeding. This is called Male Annihilation Technology (MAT). The MAT cups will be replaced several times per year.

✓ ✓ ✓ ✓ Anticipated benefits

- ■ Improved fruit fly control across the entire district
- ■ Improved market access opportunities
- ■ Reduced infestation in backyard fruit

Participation in the program is voluntary but it is hoped there will be a high level of cooperation from all stakeholders.

$ $ $ $ $ Funding for Pilot Program July 2003- June 2006

The Program will be funded by Central Burnett growers, Horticulture Australia, AusHort, Queensland Department of Primary Industries, Gayndah and Mundubbera Shire Councils.

For further information contact:

Allen Jenkin (Chairman CBAWMC) : 07 4165 4670
Russell Lyons (Shire Council Representative) : 07 4161 1377 or 07 4165 3909
Local Crop Consultants: Brian Gallagher - 07 4161 2223 Dan Papacek- 07 4165 4663 Malcolm Wallis - 07 4163 3333

APPENDIX 3 Permission to Enter Form

Permission to Enter Property

FRUITFLY FORCE

Dear Householder

To help us carry out the Area Wide Fruit Fly Management program we request that you complete this form and return it in the envelope provided.

- The enclosed information sheet explains the fruit fly control treatments to be implemented in town areas.
- Town activities will be carried out by trained Shire Council employees.
- For further information refer to the contact details below.

Thank you for your cooperation.

Contact Name _____

Address _____

_____

Daytime Phone _____

Do you have fruit trees? ❒ YES ❒ NO

I give permission for the following activities on my property

❒ Install MAT Cup ❒ Apply Protein Bait

❒ Sample Ripe Fruit

Special Requirements _____

_____

Signature _____

For further information contact:
Allen Jenkin (Chairman CBAWMC) : 07 4165 4670
Russell Lyons (Shire Council Representative) : 07 4161 1377 or 07 4165 3909
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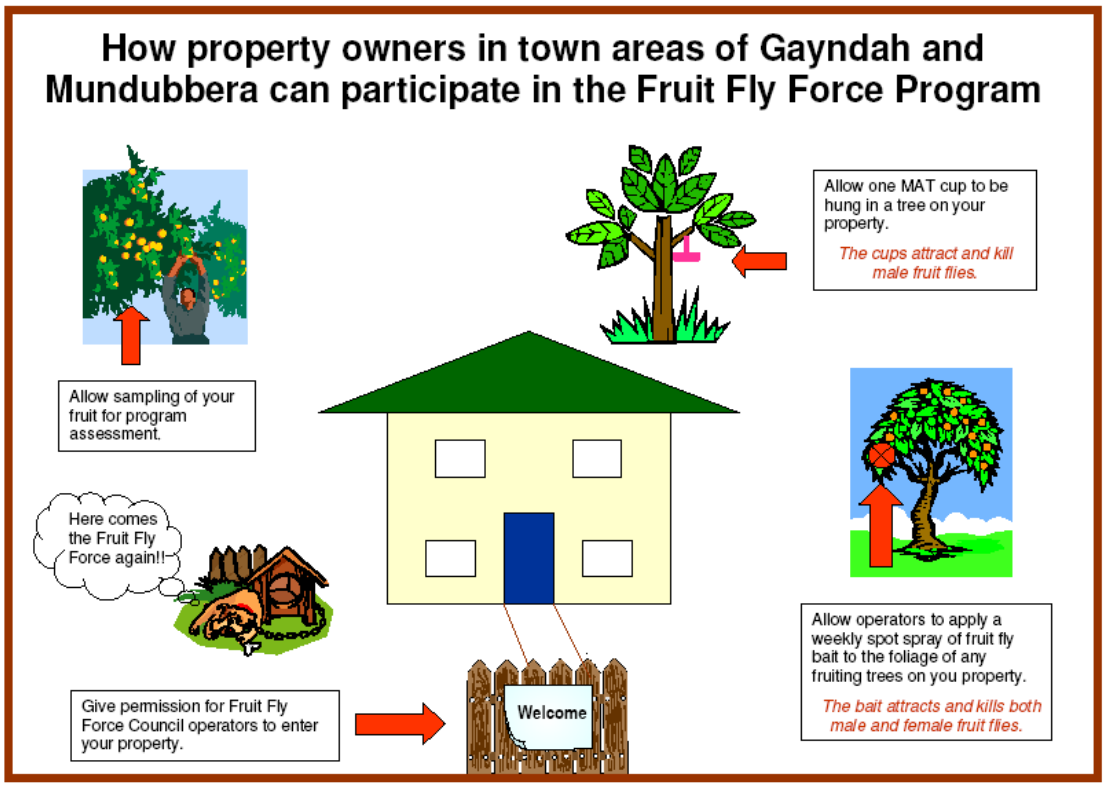
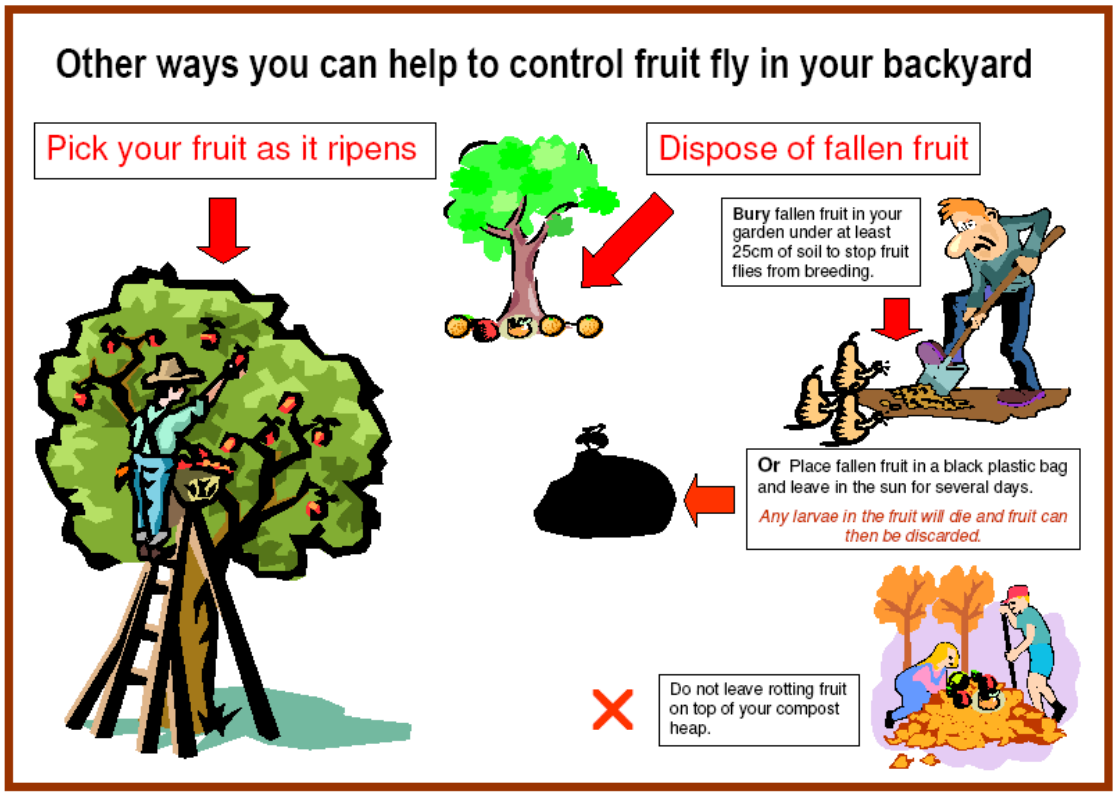
APPENDIX 4 Pictorial Instructions to Householders.





APPENDIX 5 Grower Survey

November 2005

GROWER SURVEY

Please return completed form to your local crop consultant or mail to CBAWM Grower Survey
PO Box 190
Mundubbera Qld 4626

NAME	
ORCHARD	
ADDRESS	
CROPS GROWN	

1. What fruit fly control methods did you use in 2005?

Baiting ☐ MAT cups ☐ Cover sprays ☐

2. How would you rate fruit fly problems in your crops during 2005?

	Nil	Minor	Moderate	Severe
Citrus				
Table grapes				
Mangoes				
Other				

3. What effect has the AWM program had on fruit fly control in your orchard?

No effect ☐ Minor improvement ☐ Significant improvement ☐

4. Is it worth continuing the AWM Program beyond the current project?

YES ☐ NO ☐

5. Would you be prepared to contribute financially to a cost sharing arrangement for all growers and the Shire Councils in the district to fund ongoing town treatments?

YES ☐ NO ☐

6. How has the program improved your fruit fly control? Any other comments.

AREA WIDE MANAGEMENT OF FRUIT FLIES CENTRAL BURNETT QUEENSLAND

Horticulture Australia Ltd.
Project Number AH03002

BENEFIT – COST ANALYSIS

Sarah Chambers and Mary-Ann Franco-Dixon

Industry Development
Innovation and Biosecurity Investment
Department of Primary Industries and Fisheries

June 2007

Queensland Government

Table of Contents

Executive Summary

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It is a high priority for the Queensland citrus industry to gain wider acceptance of this non-dimethoate market access protocol. The Australian Pesticides and Veterinary Medicines Authority (APVMA) is currently reviewing all uses of dimethoate based on toxicology concerns about the acute daily reference dose for this chemical. The results of this review, due for release in 2008, are likely to severely restrict many current uses of dimethoate. Loss of dimethoate postharvest treatments for citrus will cause loss of market access to South Australia, Western Australia and Tasmania. Acceptance of ICA-28 by these states would ensure maintenance of these markets. The likelihood of wider acceptance of this protocol is significantly enhanced by establishment of an AWM program. The AWM program provides an additional level of quarantine security for Central Burnett growers, complementing the already high level of on-farm control and further reducing the risk of fruit fly infestation in the packed product.

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This study has found that the AWM program has the potential to dramatically reduce the negative impact of the removal of dimethoate on the citrus industry. Without AWM, the removal of dimethoate by the APVMA would cost the Central Burnett citrus industry around $4.5 million due to the loss of access to domestic markets. With

AWM, the probability of a worst case scenario decreases and the same decision on dimethoate would cause losses of $2.3 million. Although the AWM program will not prevent the removal of dimethoate, it will reduce the negative impact on the industry by $2.1 million per year. At a discount rate of 5 percent, the Net Present Value of the AWM project and the ongoing self funded AWM program over 10 years was found to be $5.2 million, with an Internal Rate of Return of 18 per cent, and a Benefit Cost Ratio of 2.27:1. These results indicate that the project is of net benefit to Central Burnett producers and the investment costs can be justified.

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1. Introduction

In this study, the economic return on funds invested in the Area Wide Management (AWM) of Fruit Fly in the Central Burnett is estimated. The main contributors of funds to this project are Central Burnett producers, Horticulture Australia Ltd (HAL), and the DPI&F.

The aim of this paper is to determine and quantify the potential benefits of AWM in the Central Burnett, and to conduct a "project" benefit-cost analysis of the ongoing program. The benefits of AWM will be found by modelling the Central Burnett citrus industry, using a "with and without" scenario, taking into account possible changes in biosecurity trade policy viz. the decision to be made on dimethoate by the Australian Pesticides and Veterinary Medicines Authority (APVMA) and the possible extension of the Interstate Certification Assurance protocol (ICA-28) to states other than Victoria. The impact of these decisions on the Central Burnett citrus industry, with and without AWM, will be compared to find the overall program benefits of AWM. These benefits can then be applied to the benefit-cost analysis.

2. Central Burnett citrus industry

The Central Burnett district is the major citrus production area in Queensland and contributes about 80 per cent of Queensland citrus production. Seventy one orchards with a total area of more than 2000 hectares are planted with citrus in the Central Burnett. The other major horticultural crop grown in the Central Burnett is table grapes with smaller plantings of mangoes, peaches, nectarines and avocadoes.

The Central Burnett district, located 270 kilometres north-west of Brisbane, comprises the shires of Biggenden, Eidsvold, Gayndah, Mundubbera and Perry, as shown in Figure 2.1. The majority of mandarin production occurs in Gayndah and Mundubbera Shires in the Burnett River Valley. Most orchards are located along the high banks of the Burnett River and its tributaries with a few orchards on elevated well drained sites away from the river.

Citrus production in the Central Burnett 2006-07 was approximately 80 000 tonnes, of which 48 000 tonnes was sold on the domestic market, 22 400 tonnes was exported, and 9 600 tonnes was processed. Mandarins make up the largest share of production accounting for about 70 per cent, or 56 000 tonnes. The gross value of citrus production in the Central Burnett in 2006-07 is estimated at $100 million (Prospects, 2007).

Central Burnett citrus is sent to markets in Queensland, New South Wales, Victoria, South Australia, Western Australia and Tasmania. In the Gayndah area, some 30 of the more than 40 growers are members of the Gayndah Packers Cooperative Association Ltd (Gaypak). The Gaypak Co-operative packs and markets fruit under a single label and has the economies of scale to source large contracts. In particular, as this area is the largest producer of mandarins in Queensland, it would be expected that fruit from this area would form a significant part of the 14 049 tonnes of mandarins exported from Queensland in 2005-06. A significant portion of the lower grade citrus is sent to the juicing plant in Mundubbera.

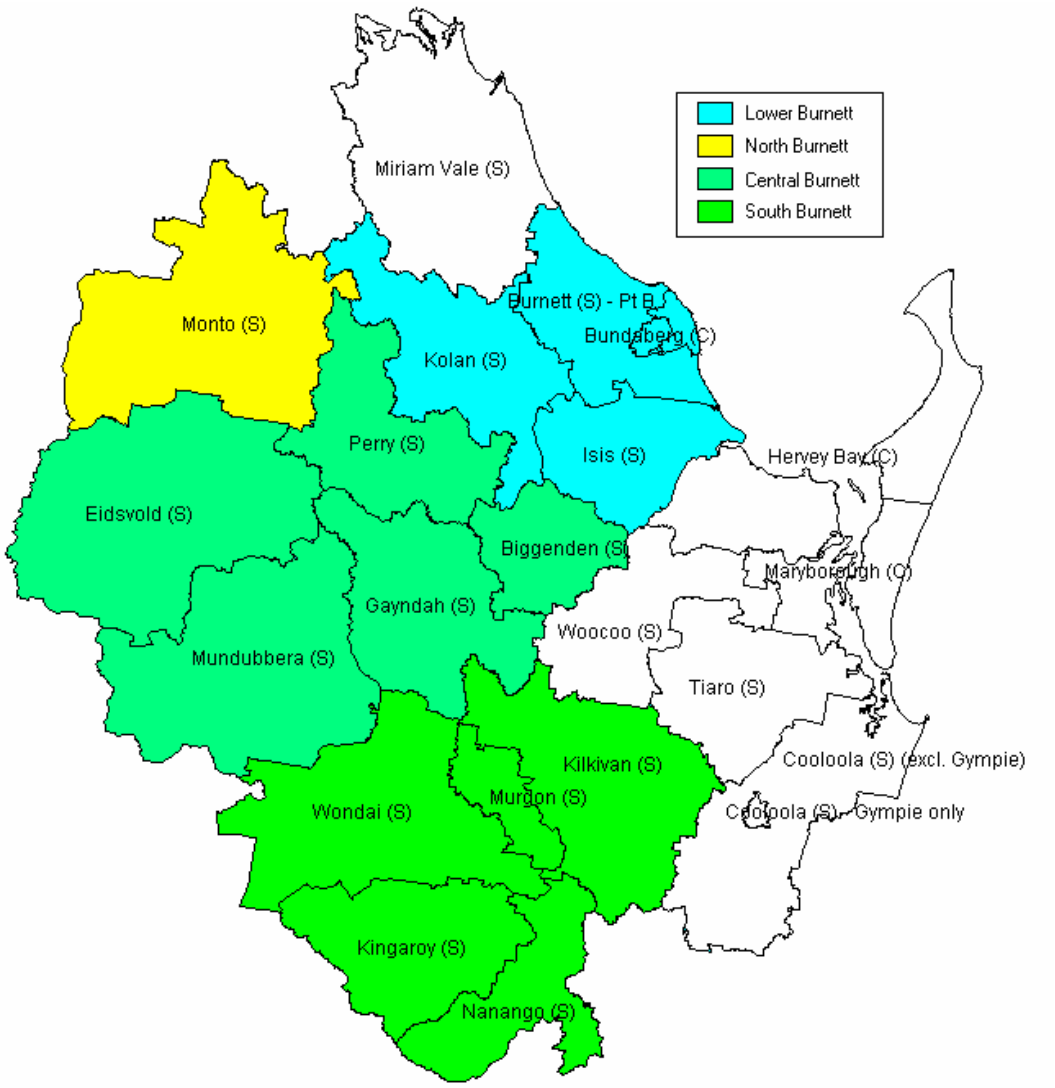


Figure 2.1 Map showing location of Munduberra and Gayndah Shires in the Central Burnett

3. Fruit fly problem

Of the 278 species of Tephritidae (fruit flies) which occur in Australia only eight are recognised as economic pests with the Queensland fruit fly (*Bactrocera tryoni*) being the most widespread and the most damaging. This species is endemic to the northern and eastern parts of Australia including the Central Burnett region. Fruit flies impose a significant cost on horticultural production every year. The economic cost of fruit flies to Australia alone is estimated at $500 million per annum (Colquhoun 1998).

3.1 On-farm implications

3.1.1 Production

Fruit flies are attracted to host plants when fruit is developing. Different fruit fly species have different host ranges. Fruit flies feed and breed around their host plants and lay eggs in the ripening fruit (Drew and Romig 1997). Larval development inside stung fruit causes extensive rotting which makes fruit unsaleable and can result in significant crop losses if field controls are not applied.

3.1.2 Control

In commercial plantings of most fruit fly host commodities, control is typically carried out on a routine basis because of the potential losses from fruit fly infestations. Fruit fly management generally involves the application of insecticides, either as cover sprays or as foliar spot sprays when the insecticide is mixed with a protein attractant such as yeast autolysate.

Integrated Pest Management (IPM) has been in practice for more than 20 years in the Central Burnett district, and regular protein baiting on most orchards has been employed as part of the program. Geographic factors, climatic conditions, and current on-farm fly controls result in very low fruit fly numbers across the entire Central Burnett district in the winter months during the citrus season.

In a recently completed DPI&F – HAL funded project (AH03002), an area wide approach to fruit fly management in the Central Burnett has been trialled for the first time. This has involved a coordinated approach to improving fruit fly control over an entire region through implementing baiting and Male Annihilation Technology (MAT) in all host crops (citrus, table grapes and mangoes) and in backyard fruit trees in the towns of Gayndah and Mundubbera. In MAT, wicks dosed with male lure and insecticide are placed throughout the orchard to attract and kill male flies on a year round basis.

3.2 Environmental implications

Integrated Pest Management as practised in Central Burnett citrus orchards for many years involves minimal use of pesticides and heavy reliance on biological control agents for citrus insect pests. Fruit fly control based on protein baiting and MAT is highly compatible with this system and has minimal environmental impact.

3.3 Quarantine implications

Queensland fruit fly is the most significant quarantine market access barrier for Central Burnett citrus necessitating pre-harvest and post-harvest measures for both interstate and export trade. Access to South Australia (SA), Western Australia (WA), and Tasmanian interstate markets require that all fruit undergo post-harvest chemical treatment with dimethoate. A two week cold disinfestation treatment is approved for interstate trade but is rarely implemented because it is not economically feasible due to high cost, lack of facilities and treatment time. Queensland citrus trade to these markets is worth approximately $15 million per year.

3.3.1 Interstate Certification Assurance Scheme (ICA-28)

The national Interstate Certification Assurance (ICA) Scheme was developed to provide an efficient and effective alternative to traditional inspection and certification of plant health by government inspectors.

The scheme utilises quality management principles as the basis for accrediting businesses to issue certificates of plant health called Plant Health Assurance Certificates. Certificates issued by accredited businesses are accepted by the

quarantine authorities of all Australian states and the Northern Territory as verification of the conformance of consignments of plants and plant products with applicable quarantine movement requirements.

ICA-28 is a market access protocol that enables producers to take a systems approach to fruit fly control by substituting preharvest bait spraying and postharvest inspection for the postharvest use of dimethoate (Table 3.1). At present it is accepted only by the Victorian quarantine authorities. Although this alternative treatment is available, many growers still use dimethoate treatments to access Victoria, mainly because of the convenience of putting all fruit through the postharvest treatment line in centralised packing sheds thus enabling access to all interstate markets.

Table 3.1 Interstate Certification Assurances (ICA) requirements for dimethoate in Australian States

State	ICA	Explanation
Queensland	N/A	Q-Fly already exists
New South Wales	N/A	Q-Fly already exists
Northern Territory	N/A	Q-Fly already exists
Victoria	ICA-28	Pre-harvest baiting and post-harvest inspection
	ICA-01	
	ICA -02	
South Australia	ICA-01	Dipping with dimethoate
	ICA-02	Flood spraying with dimethoate
Western Australia	ICA-01	Dipping with dimethoate
	ICA-02	Flood spraying with dimethoate
Tasmania	ICA-01	Dipping with dimethoate
	ICA-02	Flood spraying with dimethoate

3.3.2 Australian Pesticides and Veterinary Medicines Authority (APVMA)

The Australian Pesticides and Veterinary Medicines Authority (APVMA) is the national independent regulator of pesticides and veterinary medicines and was created under the Department of Agriculture Fisheries and Forestry. This authority is currently reviewing the use of dimethoate in fruit fly control because of toxicological, occupational health and safety, residue and trade concerns. A consequence of the review may be that the insecticide can no longer be used as a postharvest treatment, without which, access of fruit to the SA, WA and Tasmanian markets may be denied.

Investigations are being undertaken into two different safety levels for dimethoate residues on fruit with edible and non-edible peels: the acute reference dose (ARfD) which is the amount (measured in mg of pesticide per kg bodyweight) that is safe to consume in one meal or in one day, and the acceptable daily intake (ADI) which is the amount that is safe to consume every day on an ongoing basis.

In the case of citrus, the acceptable levels of residue will differ depending on the thickness of the peel in relation to the size of the fruit. Therefore there is still much uncertainty as to what fruit will be subjected to restrictions on dimethoate usage.

3.3.3 Export Implications

Currently the access of Queensland citrus to the United States is blocked by both the presence of Queensland fruit fly and a fungal disease called citrus black spot.

Incorporating AWM as a component in a systems approach to fruit fly management may well assist meeting fruit fly phytosanitary requirements to access the US market, but until an effective quarantine management system for citrus black spot is developed, the negotiations will not progress. The DPI&F project Asian Markets for Horticulture Initiative (AMHI) is combining with HAL and the Queensland Citrus industry and contributing more than $125 000 in 2006 and 2007 to accelerate the development of improved preharvest and postharvest control methods for citrus black spot.

4. Description of the Central Burnett Area Wide Management (AWM) Project

The implementation of AWM for fruit flies in endemic areas was identified as high priority during a national fruit fly research and development meeting convened by HAL in 2001. A consultant, Keith Jorgensen, was commissioned by HAL to undertake a feasibility study and the Central Burnett was identified as having the highest potential for successful implementation of such a program. This study led to the funding and approval in July 2003 for a pilot AWM program to be undertaken in the Central Burnett District by DPI&F.

The Central Burnett project (HAL Project AHO3002) was approved and began in July 2003 and ended in May 2007. A total of $3.3 million was allocated to the project over 3 years. The aims of the project were:

- To improve fruit fly control across the entire district by implementing additional control strategies in commercial orchards and by implementing controls in the town areas for the first time.

- To specifically target the spring fruit fly population explosion in the Central Burnett in the hope that reducing fly numbers at this time would significantly reduce fly pressure at the beginning of the next citrus season in January and eventually lead to an overall reduction in fruit fly pressure throughout the year.

- To minimise breeding in summer fruiting hosts in town areas (e.g. loquats, backyard citrus and abundant mango trees).

- To use AWM as a component in a systems approach to achieving quarantine security to expand current interstate and export markets.

4.1 Project outputs

The main output of the project has been the implementation and adoption of AWM in the Central Burnett district. The AWM scheme involved not only the improvement in the existing baiting procedures but also the use of MAT across the entire area, in

orchards and in town areas. Detailed results of the project are presented in the Project Final Report August 2007 by the DPI&F research team.

4.2 Project outcomes

One of the main aims of the AWM program was to enhance market access opportunities in general for all fruit fly host commodities in the Central Burnett. For citrus, a specific aim was to implement an additional risk management measure as the basis for negotiating wider acceptance of ICA28 for interstate trade.

If the ICA 28 is extended, then the possible decision by the APVMA to ban the use of dimethoate as a postharvest treatment for citrus will have no effect on the Queensland citrus industry.

The AWM project has also led to improved fruit fly management in all fruit fly host commodities with the potential to reduce the dependence on chemical insecticides for fruit fly control.

A significant outcome of the project has been very strong support from all stakeholders for AWM to continue as a self–funded program following the completion of the pilot program (Phase 1). The ongoing program will continue to be managed by the AWM committee and DPI&F will continue to have a scientific advisory role (now approved to commence as HAL Project CT06046 – Area wide management of fruit fly – Central Burnett Phase 2).

5. Methodology

This section will outline the methodologies used in calculating the results of this study.

5.1 State Contingency Analysis

The economic assessment of providing biosecurity measures includes estimating the of dollar values of the potential outcomes of a change in trade policy. The state contingency approach is a way to deal with the intrinsic risks and uncertainty of this policy issue. Arrow (1953) and Debreu (1952, 1959) developed the simple idea of state-contingent commodities – those whose delivery is contingent on the occurrence of a particular state of nature.

The state contingent approach allows one to explicitly define the risk associated with each possible state of nature, whereas the expected utility approach merges all states of nature into one by using a weighted average. By defining each state of nature it is possible to avoid losing the best and worst cases in the ‘noise’ of an evaluation and one moves away from a stochastic model to a non-stochastic model which allows one to enumerate uncertainty. Stipulating all concerns as a state of nature creates a simple but clean model that is easy to explain.

Adamson (2006) argues that a state contingent approach can be implemented into the current practices of biosecurity risk analysis very easily. He provides a framework of

analysis using a series of tables that assist in the organisation of complex problems, and ultimately lead to the assignment of a dollar value for each possible scenario depending on the associated state of nature. The first step involves the use of decision trees to help to set the states of nature.

The states of nature refer to the potential impacts on the industry depending on the outcome of the decisions. For example in this study there are two independent trade policy decisions to be made where the outcomes are uncertain. Determining the states of nature requires that the potential outcomes of each decision be defined in terms of its likely impact on the industry. State contingent analysis stipulates that for every state of nature there is a known probability and that this probability is not dependant upon the expected-utility hypothesis (Chambers & Quiggin, 2000). It therefore allows one to explicitly define the risk associated with each possible state of nature.

In the case that there is more than one relevant trade policy decision being made, it is possible to apply a generalised pay off matrix to account for the impacts of the different combinations of trade policy changes. This can be useful in organising all of the potential outcomes, their values and their probabilities, so that each is explicitly defined, and the total value of the impact on the industry can be found as the sum.

In this way the industry can be modelled to show the impact of trade policy decisions, under different management strategies. For example the AWM project has been undertaken as a management strategy to mitigate the risk of the APVMA trade policy decision, which will reduce the probability of a worst case outcome for the citrus industry. The state contingency approach can be used to compare the benefits of different management strategies to the same set of trade policy decisions.

The multi-period benefit table can be used if the benefit of the management strategy will be felt over a number of years. It allows one to show the probability of occurrence of the impact of the trade policy decision or the effect of the management strategy over a period of time. The annual benefits can then be applied to the benefit cost analysis.

5.2 Benefit-Cost Analysis

The method used to evaluate and compare the benefits flowing from the AWM of fruit fly program is a project benefit-cost analysis (BCA). The project BCA values all project inputs and outputs at private market prices (does not include tax, transfer payments etc.) and determines whether the project is efficient from a market perspective (Campbell and Brown, 2005).

The benefits of AWM are found using a with-and-without approach, which calculates the expected future value of the Central Burnett citrus industry with and without AWM. By subtracting the without-value from the with-value the total benefit of AWM on the industry is calculated. Benefits and costs are compared over time, using a discount rate. In this study a 5 per cent discount rate was for a conservative estimate. The BCA is performed over a 10 year period (2004 to 2016), as the benefits of the project are considered to be short term due to the likelihood of policy change or structural adjustment (Discussion).

The BCA framework uses research costs and the benefits of the research to derive the net present value (NPV) and benefit-cost ratio (BCR) of the project.

5.2.1 Net Present Value (NPV)

The NPV of the research program is expressed as the difference between the present value of past and future benefits and the present value of past and future costs.

Present values in this study are found in 2007 dollar terms. Firstly all values expressed in constant dollar figures, which involves adjusting past benefits and costs for inflation using the CPI. The present value of past and future benefits and costs is estimated by compounding or discounting the annual net cash flows to represent the opportunity cost of alternative use of funds. A positive NPV indicates that the project is profitable.

NPVs are also used to choose or rank alternative projects with the same cost. For example, if Project A has an NPV (A) greater than Project B's NPV (B), then Project A should be chosen (Campbell and Brown, 2003). Essentially, NPV measures the extent to which a project is a better (NPV>0) or a worse (NPV<0) use of scarce resources than the best alternative[1].

5.2.2 Benefit Cost Ratio (B/C ratio)

A B/C ratio is the discounted stream of benefits divided by the discounted stream of costs. A project yields a net social benefit (that is, it is profitable) if the B/C ratio exceeds unity, thus indicating a positive NPV. Thus, if the BCR ratio is greater than or equal to one, then the project may be accepted. If the BCR ratio is not greater than or equal to one, then the project may be rejected (Campbell and Brown 2003). In contrast to NPV, BCR is used to compare projects with different costs.

5.2.3 Internal Rate of Return (IRR%)

With both the NPV and B/C Ratio, a discount rate must be selected. If a discount rate were adopted which resulted in an NPV equal to zero or a B/C ratio equal to unity, then that rate is the IRR. The IRR represents a "break-even" discount rate for a project or the maximum rate of interest in real terms that could be paid on capital invested in the project for it to break-even. A project is generally considered acceptable (profitable) if the IRR exceeds a pre-established social discount rate (in this case 5 per cent).

5.3 Conditions used for Analysis

The Central Burnett produces citrus of varying quality which is sold on the domestic and export markets. First and second grade fruit is sold to both domestic and export markets. A premium is paid to growers for fruit sold on the domestic market, due to lower transport costs compared to exported fruit. There is potential to increase supply of citrus to export markets in Asia.

[1] In this case the discount rate acts as a proxy for the best alternative (i.e. a different investment).

Fruit is generally sent to one of the large marketing groups (Gayndah Packers or Sweetee), where the fruit is graded, treated, packed and marketed. As the procedure of dipping fruit in dimethoate is part of a larger system of marketing the fruit the cost of the postharvest dimethoate treatment is considered to be negligible (Graham Mcosker 2007, pers. comm.).

There is an 85 per cent probability that postharvest use of dimethoate will be disallowed or made conditional by type for citrus, by the APVMA (Chris Adrianson 2007, pers. comm. 2007). In this study a window of 5 years 2006-2011 was used as the probable time frame for this decision to be made. Over this time frame there will be a cumulative probability of occurrence, and in 2011 onwards the full impact of the decision will be felt (100 per cent).

As there is no data relating to postharvest residue levels of dimethoate on citrus, it is assumed the APVMA will take a precautionary approach to decision making. There is higher likelihood that postharvest use of dimethoate will be disallowed for mandarins than for other citrus due to the low skin to fruit ratio (Chris Adrianson 2007, pers. comm.). Lemons, limes, oranges and grapefruits have thicker skin and therefore there is a lower risk of ingestion of residue

Due to the AWM project there is a 70 per cent probability that the ICA-28 will be extended to include at least one other state (Annice Lloyd, pers. comm. 2007). Without AWM there was only a 20 per cent probability of the extension of ICA-28. The proposal for the extension of ICA-28 was put forward during a meeting of the Domestic Quarantine and Market Access Group in May 2007 (Cameron Tree 2007, pers. comm.). The SA, WA and Tasmanian groups are seriously considering this proposal, and SA is considered to be the most likely to accept in the near future. In this study, it is assumed that the ICA decision will occur before the APVMA decision, and will not change in the short term.

Other citrus producing regions of Queensland that have not implemented AWM have not been considered in this study. It is likely that if they were to adopt the AWM technology the results calculated in this study would be underestimating the benefits to the industry.

5.4 Applying State Contingency Approach

There is a risk that the Queensland citrus industry could lose access to some domestic markets if the APVMA decides to ban the postharvest use of dimethoate. It is hoped that the implementation and continuation of AWM will assist in the negotiations to extend the ICA-28 so that the APVMA decision will not have a negative effect on the citrus industry. However, this outcome is not guaranteed, and there is a risk that these negotiations will not succeed.

The implications of the loss of these markets could include:

- A decrease in domestic demand for Queensland citrus, which will lead to an oversupply in the remaining markets, and may lead to fruit being sold at unviable prices.

- The increase in the amount of fruit sent to export markets where the price is lower, which will oversupply the market and lead to further price decreases.

5.4.1 Possible Scenarios

The potential outcomes of the ICA-28 negotiations can be described as best, middle or worst case in so far as economic outcomes to Queensland producers are concerned. These have been outlined below:

A. Best Case: Extension of ICA-28 to all other States
B. Middle Case: Extension of ICA-28 to SA only
C. Worst Case: No extension of ICA-28

The potential impact of an APVMA decision on the Queensland citrus industry could vary from no impact, to medium or high impact, depending on the ruling. The states of nature of this decision could be:

A. No impact: Dimethoate allowed for use with all citrus (as at present)
B. Medium impact: Dimethoate banned for use with mandarins
C. High impact: Dimethoate banned for use with all citrus

The possible states of nature outlined above were applied to a decision tree to identify the scenario. Scenario 1 in this case is describing the outcome in which no change will occur to the citrus industry as a result of these two decisions. Scenario 2, 3, 4 and 5 each vary in their impact depending on the state of nature of the outcome. With the scenarios identified, they can now be organised into a generalised pay off matrix (Table 5.2).

Table 5.1 IRA pay off matrix

Outcome of ICA Negotiations	Outcome of APVMA Decision		
	No impact	**Medium impact**	**High impact**
Best case	Scenario 1	Scenario 1	Scenario 1
Middle case	Scenario 1	Scenario 2	Scenario 3
Worst case	Scenario 1	Scenario 4	Scenario 5

The probability of occurrence for each scenario needs to be estimated for the industry with and without AWM. The probabilities are based on estimates of industry experts, which are outlined in the assumptions of this paper. With AWM there is a higher probability that either the best or middle case outcome will result from the ICA negotiations (70 per cent) than without AWM (20 per cent). Therefore the only difference between the industry forecast with and without AWM is the probabilities of occurrence for each scenario.

Table 5.2 IRA Payoff Matrix Probabilities with AWM

Outcome of ICA Negotiations	Outcome of APVMA Decision			
	No impact	Medium impact	High impact	Total Probability
Best case	3%	9%	8%	20%
Middle case	8%	23%	20%	50%
Worst case	5%	14%	12%	30%
Total probability	15%	45%	40%	100%

Table 5.3 IRA Payoff Matrix Probabilities without AWM

Outcome of ICA Negotiations	Outcome of APVMA Decision			
	No impact	Medium impact	High impact	Total Probability
Best case	1%	2%	2%	5%
Middle case	2%	7%	6%	15%
Worst case	12%	36%	32%	80%
Total probability	15%	45%	40%	100%

The next step is to determine the impact, in dollar terms, of each of these scenarios on the Central Burnett citrus industry. The impact is measured as the difference in producer surplus between the "no change" scenario (1) and each of the other four scenarios. The change in producer surplus was found by modelling the industry under the conditions of the different scenarios, and is explained in the next section.

6. Project benefits

AWM increases the certainty of domestic market access because it underpins the extension of ICA-28 to other states, which will in turn mitigate the risk of losing markets in the case that postharvest use of dimethoate is banned by the APVMA.

Therefore the benefit of AWM is the value of potential loss mitigation, because there is less chance of a negative outcome with AWM compared to without AWM.

The extent of the impact is found by calculating the change in producer surplus for each scenario, and applying the corresponding probability of occurrence with and without AWM. The sum of these values will give the estimated impact on industry of the APVMA decision with and without AWM, and the difference is the value of the benefit of AWM to the Central Burnett citrus industry.

6.1 Measurement of Producer and Consumer Surplus

A surplus is generated when a consumer is able to buy a unit of a good at a price lower than her willingness to pay for that unit, or when a producer is able to sell a unit of a good or factor of production at a price higher than that at which he would willingly part with that unit (Campbell and Brown, 2005). The concept of producer and consumer surplus is used by economists as a way to measure changes in economic welfare.

Consumer surplus is a measure of the benefit received by the consumer, or the difference between what the consumer is willing to pay and what the consumer has to pay. Producer surplus is the amount producers receive above and beyond the minimum price that would be required to get them to produce and sell their output (Mansfield, 1997). In this study the long run minimum price has been used, which is the fixed cost of production. To illustrate, the producer surplus from the production and sale of the equilibrium output of a good is shown by the shaded area- the area above the supply curve and below the price (Figure 6.1).

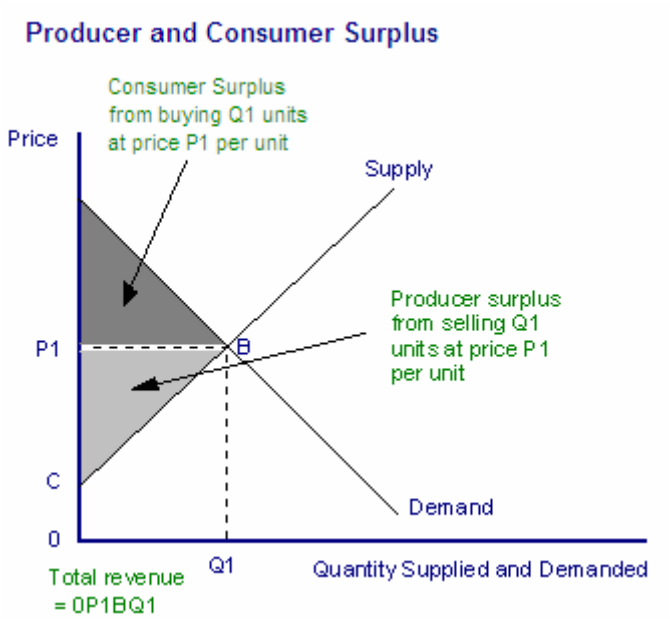


Figure 6.1 Producer and Consumer Surplus
Source: Mansfield 1997

6.1.1 Determining the Impact on the industry

Each scenario will displace different quantities of fruit, which will need to be diverted from the lost markets to the remaining markets. The total quantities of fruit being traded from Queensland will not change in the short run as a result of the decisions; however quantities to the remaining domestic and international markets will increase as a result of the redirection. In this study the changes in surplus are calculated on an annual basis.

The loss of markets as a result of the APVMA decision would lead to an overall downward shift in the domestic demand curve for citrus. This will lead to the redistribution of fruit which is equivalent to an outward pivot in the supply curve of the other markets, for example the shift from supply 1 to supply 2, and therefore a change in consumer and producer surplus (Figure 6.2).

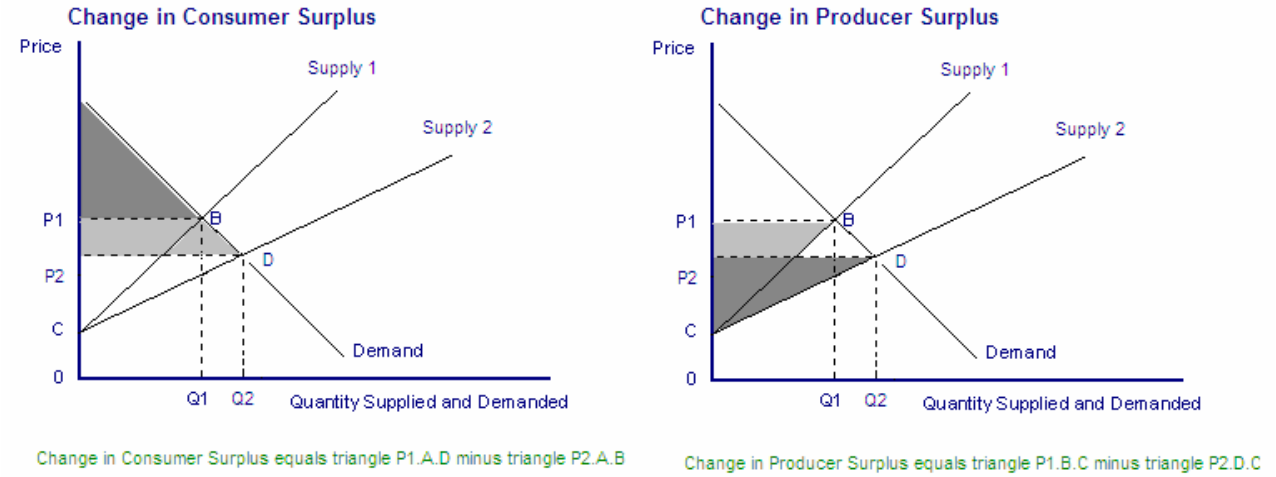


Figure 6.2 Shift in supply, leading to change in producer and consumer surplus
Source: Mansfield 1997

This redistribution will affect Australian consumers of Queensland citrus. It will lead to short term positive changes in consumer surplus in some States, where there is a surplus of fruit and the price is lower (QLD, NSW and Victoria). However there will be short term negative changes in consumer surplus in the States where Queensland fruit is no longer allowed (SA, WA and Tasmania) because the shock of the reduced supply of citrus would increase prices. These changes will be short term because the industry is likely to undergo structural adjustment in order to restore the balance of supply and demand. For example, South Australian citrus producers are likely to divert more citrus from export markets to the domestic market (where the price is higher) as a result of a block on Queensland citrus. Similarly the Queensland citrus industry would need to expand their markets, both export and domestic, or cut back production. Changes in consumer surplus are likely to be short term, and the positive and negative changes in different States will cancel each other out. As this study is using a project BCA the consumer surplus has not been quantified or used, as it is not considered a direct project output.

The redistribution of fruit will lead to subsequent increases in quantity supplied to the remaining markets and decreases in price. The extent of these changes to producer surplus is measured using the own-price elasticities of demand and supply.

6.1.2 Own Price Elasticity

Price elasticity can be interpreted as the percentage change in quantity demanded/supplied given a percent change in the price of that commodity, ceteris paribus. If elasticity of demand for a commodity is price elastic ($|E|>1$), an increase in the quantity supplied will mean that percentage decrease in the price the consumers are willing to pay for the commodity will be smaller than the percentage increase in supply. If the elasticity of demand for a commodity is inelastic ($|E|<1$) there will need to be a greater percentage drop in price in order to encourage consumers to increase consumption to accommodate an increase in quantity supplied. The formula for own price elasticity of demand (OPED) of demand is given by:

$$OPED = \frac{(Q2-Q1)/((Q1+Q2)/2)}{(P2-P1)/((P1+P2)/2)}$$

P1 is the original price
P2 is the new price
Q1 is the original quantity
Q2 is the new quantity.

This equation is used to determine the new equilibrium price as a result of a change in quantity or vice versa.

6.1.3 Citrus Marketing Information

Marketing information for citrus in the Central Burnett was gathered through consultation with industry representatives as well as literature reviews. For the purpose of this study citrus was split into two groups: mandarins, and other, which is made up of oranges, lemons, limes and grapefruit. The prices used are meant to be a general representation of prices producers can expect for produce in an average year.

Prices are known to fluctuate seasonally, and the figures given in Table 6.1 have been chosen after discussions with the Queensland Citrus Growers Inc, as well as Policy and Investment Advice[2]. Mandarin export price was determined from export data from the Australian Citrus Growers Inc.

Table 6.1 Marketing information for citrus from the Central Burnett

	Mandarins	Other
Price	**($/t)**	**($/t)**
Domestic	1 500	1 350
Export	1 300	1 250
Processing	30	30
Break even	1 000	900
Costs	**($/t)**	**($/t)**
Fixed cost of production	368	368
Elasticities of demand		
Domestic	-0.8	-1.44
Export	-1.44	-1.44

The fixed cost of production was based on the figures given in the Agrilink Citrus Information Kit, 1997. The fixed costs from a typical mixed variety 18 ha orchard had been calculated based on information gathered by Hardman (1994) in the Economics of Citrus Growing - Central Burnett.

Price elasticity of demand was found for mandarins and other citrus based on the literature and other assumptions. A representative domestic price elasticity of demand for mandarins was not found in the literature. In this study it is assumed to be -0.8, because mandarins are considered to be a sought after commodity that will be in demand, even if there is a change in price. The domestic price elasticity of demand for other citrus was based on work completed by Jetter *et al.* (2000), who identified elasticity of demand for domestic orange, lemon/lime and grapefruit in California. It is assumed that these figures can be representative of domestic elasticity of demand for these commodities in Australia, because both the United States and Australia are considered to be higher income developed countries with similar citrus markets and consumer preferences. These elasticities were weighted according to their proportion of citrus production, and the elasticity value of -1.44 was found to be representative of the entire Other Citrus category (Table 6.2).

Table 6.2 Elasticity of Demand for Domestically Produced Citrus in California

	Elasticity of Demand	Proportion of Other Citrus
Oranges	-1.2	40%
Lemons & Limes	-0.5	48%
Grapefruit	-6	12%
Total Other Citrus	-1.44	100%

[2] It should be noted that information on market prices is not easily attainable from the industry due to its fragmented nature.

A separate study by Sparks (1992) identifies the export price elasticity of demand for Australian oranges in Singapore as -1.44. For the purpose of this study oranges have been taken as representative of both mandarin and other citrus.

6.1.4 Citrus Production and Distribution of Sales

The Queensland citrus industry was estimated to produce 100,000 tonnes of citrus in 2006, and is worth approximately $120 million. The Central Burnett region generally produces about 80 per cent of Queensland production. Around 70 per cent of Queensland citrus production is mandarins, which is worth close to $90 million (Table 6.3).

Table 6.3 Estimated Quantities of Citrus Production 2006

Production of Citrus	QLD		Central Burnett	
	All	Mandarin	All	Mandarin
Percentage of Production (%)	100%	70%	100%	70%
Production (t)	100 000	70 000	80 000	56 000
Estimated GVP ($)	123 640 000	86 548 000	99 912 000	70 985 600

The destination of sales of citrus to the three markets is shown in Table 6.4. Sixty per cent of first and second grade fruit is sold on the domestic market at a premium price. The export market receives about 28 per cent of citrus from the area. Any fruit that is deemed not suitable for sale is sent to processing plants to be converted to juice or other products. This is not considered a viable market as producers are only paid a salvage price for this fruit, which is generally the cost of transport. In the Central Burnett this is about 12 per cent of production, which is much lower than that of coastal areas.

Table 6.4 Destination of Sales of All Citrus from the Central Burnett

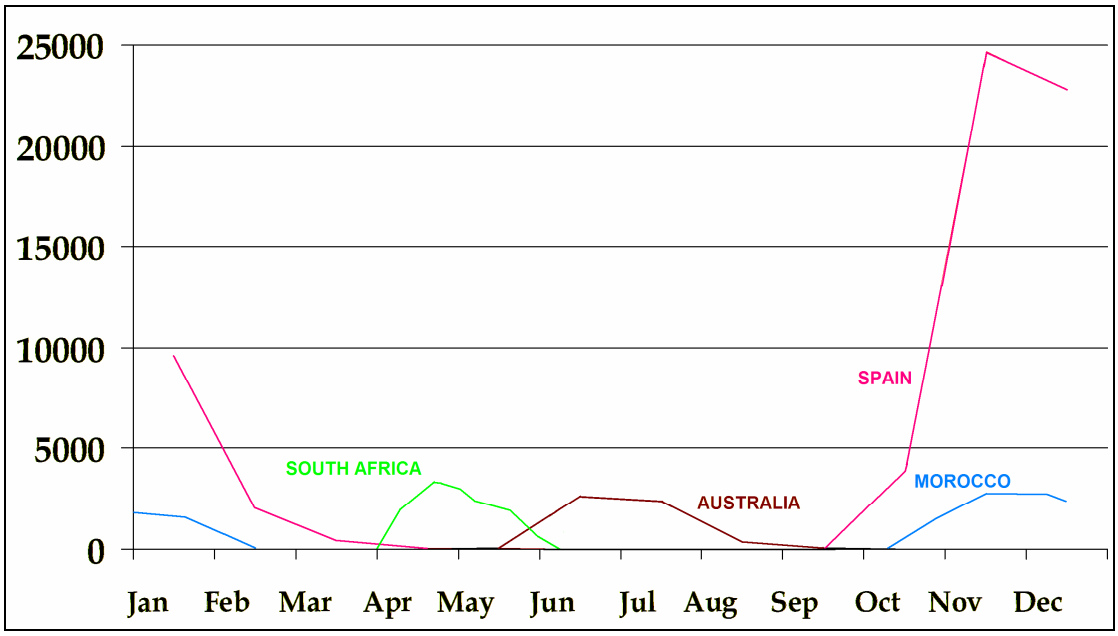
Destination of Sales (all citrus)		Quantity	Value
Domestic Markets	**%**	**tonnes**	**$'000**
NSW	30%	14 400	19 325
QLD	25%	12 000	16 104
Victoria	25%	12 000	16 104
SA	15%	7 200	9 662
Tasmania, WA	5%	2 400	3 221
Total Domestic	100%	48 000	64 416
Domestic % of total	**60%**	48 000	64 416
Export % of total	**28%**	22 400	28 784
Processing % of total	**12%**	9 600	288
Total	**100%**	**80 000**	**93 488**

6.2 Export market

A possible economic benefit of AWM is future market access to the US market for mandarins. The two quarantine issues currently restricting access to this market are the presence of Queensland fruit fly, and a fungal disease called "citrus black spot". It is hoped that the combination of AWM as a highly effective field control, with postharvest disinfestation treatment will achieve the desired level of fruit fly

quarantine security to access this market. South Australian mandarins are currently exported to the US and are receiving prices around $2500/tonne. Australian/Queensland mandarins are counter-seasonal to all production in the northern hemisphere, and are therefore in the unique position of having very little competition during the harvesting window (Figure 6.3)

Figure 6.3 US Mandarin Imports 2000-2003



Source: FATUS

Citrus black spot is a fungal disease that blocks access for Queensland citrus to the United States. AMHI is combining with Horticulture Australia Limited and the Queensland Citrus industry and contributing more than $125 000 in 2006 and 2007 to accelerate the development of improved preharvest and postharvest control methods for citrus black spot. As the access to the US market is dependent upon the success of this research on black spot, the possible benefits of AWM on export market access have not been included in this study.

7. Project Costs

The costs of AWM included in this study include the initial investment costs of the pilot project as well as the ongoing costs to maintain the program. The main sources of funding have been the DPI&F, HAL and Central Burnett Shire Councils and producers.

7.1 Costs of the Central Burnett AWM scheme

The total cost of the pilot project over the three years (2004 to 2006) was $2.4 million in constant dollar figures (Table 7.1). This figure was based on the total HAL funds for the research project plus the value of other contributions from DPI&F, the Central Burnett Shire Councils, and the cost to growers to implement the additional control strategy (MAT) which was initiated as a component in the AWM program The cost to producers for orchard treatments (eg baiting) and consultant services which were

already being undertaken prior to the commencement of AWM were not included as a cost for the purposes of this analysis.

Table 7.1 Project Costs in Constant Dollar Figures (2007)

Year	Salaries & On costs	Corporate Operational and Facility Support Overhead	Travel expenses	Operating expenses	Capital	Total Project Costs
	$'000	$'000	$'000	$'000	$'000	$'000
2004	277	155	9	431	5	877
2005	271	151	8	351	0	781
2006	263	147	8	341	0	759
Total						2 417

The pilot program funded by HAL was completed in May 2007. The ongoing AWM program will be funded by the Central Burnett horticultural community (citrus and non-citrus growers) and will continue to be managed by the AWM committee. The DPI&F Market Access Team will continue in a scientific advisory role for the next four years (HAL project Central Burnett AWM – Phase 2).

The ongoing costs of the program is $208 000 per year, which will be paid by Central Burnett producers (

Table 7.2). Growers will be responsible for the costs of purchasing MAT treatments ($130,000) and applying them in their own orchards ($18,000). The cost of applying baits to the town areas and of overall supervision and coordination of the program will require an additional contribution of $60 000 per year to the AWM committee. This will be raised through voluntary contributions ($30 per hectare of fruit fly host commodities) by local producers.

Table 7.2 Ongoing Program Costs

Ongoing costs to producers	
	$'000
MAT carriers	130
MAT application	18
Project maintenance	60
Total	208

7.2 Source of funds

Of the $2.4 million invested in AWM over the first three years, HAL provided 47 per cent ($1.1 million), DPI&F also provided 47 per cent, and the rest was provided by other contributors such as growers and shire councils (Table 7.3). It should be noted that as main provider of salary for this project the corporate overhead and facility support overhead was added as a DPI&F cost.

Table 7.3 Funding Sources in Constant Dollar Figures (2007)

Year	DPI&F Costs	HAL Costs	Other Contributor Costs	Total
	$'000	$'000	$'000	$'000
2004	391	438	48	877
2005	382	352	47	781
2006	371	342	46	759
Total	1,145	1,132	141	2,417
% of Total	47%	47%	6%	100%

8. Results

8.1 Impact of AWM on the Queensland citrus industry

The annual change in producer surplus associated with each scenario is shown in

Table 8.1. Scenario 1 is taken as the status quo, representing no change to the industry as a result of the APVMA decision. The change in producer surplus is the difference between the producer surplus of each scenario and that of scenario 1. The workings and explanations of these calculations can be found in Appendix 1 and Appendix 2. In the case that ICA-28 is not extended to any other states the loss to the citrus producers would be $5.5 million if dimethoate is disallowed for mandarins and $7 million if dimethoate is disallowed for all citrus. If ICA-28 is extended to SA, under the same APVMA decisions there will be a loss of $1.66 million and $3.7 million respectively.

Table 8.1 IRA Payoff Matrix: Effect of Scenarios on Producer Surplus

Outcome of ICA Negotiations	**Outcome of APVMA Decision**		
	No Impact	Medium Impact	High Impact
	$'000	$'000	$'000
Best case	0	0	0
Middle case	0	- 1 658	- 3 707
Worst case	0	- 5 526	- 7 142

The annual total value of risk to the industry, as a result of the APVMA decision with and without AWM, can be found by weighting the value of each scenario with its corresponding probability (Table 5.2 and Table 5.3). The sum of the values of each of these scenarios gives a total value of losses to producer surplus in the citrus industry as a result of the APVMA decision (Table 8.2 and Table 8.3).

Table 8.2 Payoff Matrix with AWM: Effect of Scenarios with Probabilities

Outcome of ICA Negotiations	**Outcome of APVMA Decision**			
	No Impact	Medium Impact	High Impact	
	$'000	$'000	$'000	$'000
Best case	0	0	0	
Middle case	0	- 373	- 402	
Worst case	0	- 746	- 856	
SUM				- 2 378

Table 8.3 Payoff Matrix without AWM: Effect of Scenarios with Probabilities

Outcome of ICA Negotiations	Outcome of APVMA Decision			
	No Impact	Medium Impact	High Impact	
	$'000	$'000	$'000	$'000
Best case	0	0	0	
Middle case	0	- 112	- 121	
Worst case	0	- 1 990	- 2 285	
SUM				- 4 507

With AWM there is a lower probability of occurrence of the worst case scenario, and the value of the risk to the industry decreases to $2.4 million per year. Without AWM the sum of these losses is $4.5 million per year. Therefore the expected benefit of AWM to the Queensland citrus industry is $2.1 million.

8.2 State contingent analysis: Multi-period Benefit

In order to apply this information over several years, it is necessary to determine the general timeframes in which the ICA and the APVMA decision will be made. It is assumed that the APVMA decision is likely to be made within the five year window between 2007 to 2011 (Chris Adrianson, pers. comm. 2007). Over this period the sum of the probability of occurrence is 100 per cent. After 2011 it is assumed that the decision would have been made and the Queensland citrus industry will be feeling the full impact (100 per cent) on an annual basis. The annual benefits of AWM over 10 years taking into account the probability of occurrence the APVMA decision are shown in Table 8.4.

Table 8.4 APVMA decision

Year	Probability that result of APVMA decision will apply	Annual Benefit of AWM over 10 years
		$'000
2004	0%	0
2005	0%	0
2006	0%	0
2007	5%	107
2008	15%	319
2009	50%	1 064
2010	75%	1 596
2011	100%	2 128
2012	100%	2 128
2013	100%	2 128
2014	100%	2 128

The annual project benefits were found by applying the annual probability of occurrence of the APVMA decision with the expected annual benefit of AWM (Appendix 3). These can now be applied to the BCA.

It has been assumed that the ICA decision will be made before the APVMA decision. Although these decisions are independent of one another, if the APVMA decision proves to be detrimental to any of the States (SA, WA, and Tasmania) it is likely that

this will lead to the adoption of ICA-28 and therefore re-enable trade of Queensland citrus. This possibility has not worked into this model.

8.3 Benefit Cost Analysis

The present yearly benefits and costs of the AWM project for the years 2004 to 2014 are presented in

Table 8.5. All benefits and costs have been discounted/ compounded to 2007 values using a 5 per cent discount rate.

Table 8.5 The Present Value of Benefits and Costs of the AWM over 10 years (2004 - 2014).

Year	Present Value of Project Benefits	Present Value of Project Costs	Net Present Value of Project
	$	$	$
2004	0	1,015	-1,015
2005	0	861	-861
2006	0	797	-797
2007	106	208	-102
2008	304	198	106
2009	965	189	777
2010	1,379	180	1,199
2011	1,751	171	1,580
2012	1,668	163	1,505
2013	1,588	155	1,433
2014	1,513	148	1,365
Total	9,274	4,085	5,189

At a discount rate of 5 per cent, research project costs of $4.1 million generated benefits of around $9.3 million. This has resulted in a positive NPV of $5.2 million, and a benefit cost ratio of 2.27:1 (Table 8.6). The IRR of 18 per cent is well above the social discount rate of 5 percent and the project is deemed acceptable under this criteria.

Table 8.6 Profitability of the AWM research project and ongoing program

BCA Parameters 2004-2018	
	$'000
Total Present Value of producer benefits (A)	9 274
Total Present Value of R&D costs (B)	4 085
NPV of project (A-B)	5 189
BC ratio (A/B)	2.27:1
IRR	18%

8.4 Sensitivity Analysis

8.4.1 Prices

The price paid for Queensland citrus on the domestic and export market is subject to change, and variability in prices is not yet taken account of in this analysis. The sensitivity of the results of this analysis to a change in export and domestic prices are shown in Table 8.7. The table shows the effect on the results from a 10 per cent and 20 per cent increase/decrease in prices.

Table 8.7 Sensitivity analysis using different levels of domestic and export prices

BCA Parameters	Decreased 20%	Decreased 10%	Base Case	Increased 10%	Increased 20%
2004-2018	$'000	$'000	$'000	$'000	$'000
NPV of producer benefits (A)	7 419	8 346	9 274	10 201	11 129
NPV of R&D costs (B)	4 085	4 085	4 085	4 085	4 085
NPV of project (A-B)	3 334	4 261	5 189	6 116	7 044
BC ratio (A/B)	1.81:1	2.04:1	2.27:1	2.50:1	2.72:1
IRR	13%	15%	18%	20%	22%

As would be expected the NPV decreases with lower prices, and increases with higher prices. However it is important to note that even if prices decrease by 20 per cent the NPV of the AWM project remains positive.

8.4.2 Probabilities

Other variables assessed in the sensitivity analysis are the state contingency probabilities used 'with' and 'without' AWM. Probabilities used in the base case were based on estimates given by Annice Lloyd (2007 pers. comm.) and Chris Adriaansen (2007 pers. comm).

The sensitivity of this analysis to these probabilities is shown in Table 8.8. Scenario A explores the effect of a change in probabilities in the APVMA decision, which has minimal effect on the results of the analysis. Scenario B takes a pessimistic approach to the effect of AWM on affecting the ICA decision. The best and medium outcomes are both reduced by 10 per cent, and the worst case outcome is increased by 20 per cent. This has a significant effect on the results of the study, and causes a negative NPV. This highlights the importance of differentiating the probabilities of each state of nature as a result of specific variables. Scenario C considers the increased probability of best and medium outcomes of the ICA decision, with an expected higher NPV. Details of the sensitivity scenarios are in Appendix D.

Table 8.8 Sensitivity analysis using different state contingency probabilities

BCA Parameters	Base Case	Scenario A	Scenario B	Scenario C
2004-2018	$'000	$'000	$'000	$'000
NPV of producer benefits (A)	9 274	9 423	5 294	13 254
NPV of R&D costs (B)	4 085	4 085	4,085	4 085
NPV of project (A-B)	5 189	5 337	1 209	9 169
BC ratio (A/B)	2.27:1	2.31: 1	1.30:1	3.24:1
IRR	18%	18%	5%	26%

9. Discussion

The AWM project in the Central Burnett district has been used to mitigate the negative trade impact of the possible APVMA decision to disallow the use of dimethoate. The scope of this study has measured the benefits of this project over only a short period (eight years) because there is the likelihood of policy or industry changes in the medium term that cannot be fully taken account of in this study. If there was a negative effect on the Queensland citrus industry of losing domestic markets, and prices for citrus dropped, in the medium term it is likely that industry would adjust by producing less citrus. It is also probable that if South Australia, Western Australia or Tasmania were negatively affected by the inability to import Queensland citrus, they may be more likely to reconsider the adoption of an ICA-28. Hence, due to the possible industry and policy actions in the medium term, this study has focussed on the short term effect of AWM on the Queensland citrus industry.

This study is not without limitations. The main assumptions of the study have been based on events that have not yet occurred, hence the need for the risk approach of using probabilities. One of the main variables of this study was the probability of occurrence of best, middle or worst case outcomes from the ICA negotiations as a result of the AWM project. The probabilities used were justified as they came from industry experts and a sensitivity analysis was performed. When a pessimistic scenario was used, and the best and medium case probabilities were decreased 10 per cent the project still yielded a positive NPV. This highlights that the benefits of this project are evident even if it is considered in a pessimistic light. Despite the subjective nature of risk analysis, this does not detract from the usefulness of this analysis in determining the effect of AWM under a certain set of agreed conditions.

The AWM program is important for the citrus industry in Queensland as it has the ability to increase the probability of the best case scenario resulting from the ICA negotiations. However AWM will have no effect on the APVMA decision. In order to increase the probabilities of "no impact" on the citrus industry as a result of the APVMA decision on dimethoate, it would be beneficial for the citrus industry to conduct research into the acute reference dose (ARfD) of dimethoate on fruit after post harvest treatment. The APVMA is acknowledging research data from Europe that investigated the acceptable daily intake (ADI) of dimethoate on different fruits after pre-harvest treatments. However there is currently no data on the acute reference dose (ARfD) of dimethoate on fruit after postharvest treatment, and therefore the APVMA will be more likely to rule against its use based on the precautionary principle.

10. Conclusions

This study has found that the AWM program has the potential to dramatically reduce the negative impact of the removal of dimethoate on the citrus industry. Under this assumption the benefit of mitigating the risk to the industry of the loss of dimethoate has been quantified.

Without AWM the removal of dimethoate by the APVMA would cost the Central Burnett citrus industry around $4.5 million due to the loss of access to domestic markets. With AWM the probability of a worst case scenario decreases and the same

decision on dimethoate would cause losses of $2.3 million. Although the AWM project will not prevent the removal of dimethoate, it will reduce the negative impact on the industry by $2.1 million for each year after the APVMA decision has been made.

At a discount rate of 5 percent, the NPV of the AWM project over 10 years was found to be $5.2 million, with an IRR of 18 per cent, and a BCR of 2.27:1. These results indicate that the project is of net benefit to Central Burnett producers and the investment costs can be justified.

It should be clearly noted that the full benefits of AWM have not been calculated in this study. The AWM program in the Central Burnett provides benefits to all horticultural commodities affected by fruit fly, while this study has focussed purely on its effect to the citrus industry. However through this study it has been shown that the program is cost efficient even without all benefits included. It can therefore be assumed that the overall value of this program would be higher than that calculated in this study.

11. References

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Appendix 1: Calculation of Scenarios

Scenario 1			
Premium			
P1m	1,500	TRm	$50,400,000
Q1m	33,600	PSm	$19,017,600
P1o	1,350	TRo	$19,440,000
Q1o	14,400	PSo	$7,070,400
Export			
P1m	1,300	TRm	$20,384,000
Q1m	15,680	PSm	$7,306,880
P1o	1,250	TRo	$8,400,000
Q1o	6,720	PSo	$2,963,520
Processing			
P1m	30	TRm	$201,600
Q1m	6,720	PSm	-$1,135,680
P1o	30	TRo	$86,400
Q1o	2,880	PSo	-$486,720
Total TRm	$70,985,600		
TotalTRo	$27,926,400		
Total PSm	$25,188,800		
Total Pso	$9,547,200		
Total TR	$98,912,000		
Total PS	$34,736,000		

Scenario 2			
Premium			
EoD	-0.8		
P1m	1,500	TRm1	$47,880,000
P2m	1,401	TRm2	$47,084,211
Q1m	31,920	PSm1	$18,066,720
Q2m	33,600	PSm2	$17,359,705
Export			
EoD	-1.44		
P1m	1,300	TRm1	$20,384,000
P2m	1,300	TRm2	$20,384,000
Q1m	15,680	PSm1	$7,306,880
Q2m	15,680	PSm2	$7,306,880
Processing			
P1m	30	TRm1	$201,600
Q1m	6,720	PSm1	-$1,135,680
Total TRm	$68,465,600		
TotalTRo	$27,926,400		
Total PSm	$23,530,905		
Total Pso	$9,547,200		
Total TR	$96,392,000		
Total PS	$33,078,105		

Scenario 4			
Premium			
EoD	-0.8		
P1m	1,500	TRm1	$40,320,000
P2m	1,300	TRm2	$38,671,360
Q1m	26,880	PSm1	$15,214,080
Q2m	29,747	PSm2	$13,862,195
Export			
EoD	-1.44		
P1m	1,300	TRm1	$20,384,000
P2m	1,078	TRm2	$21,059,769
Q1m	15,680	PSm1	$7,306,880
Q2m	19,533	PSm2	$6,935,849
Processing			
P1m	30		
Q1m	6,720	TRm1	$201,600
		PSm1	-$1,135,680
Total			
TRm	$60,905,600		
TotalTRo	$27,926,400		
Total			
PSm	$19,662,364		
Total Pso	$9,547,200		
Total TR	$88,832,000		
Total PS	$29,209,564		

Scenario 3			
Premium			
EoDm	-0.8		
P1m	1,500	TR1m	$47,880,000
P2m	1,401	TR2m	$47,084,211
Q1m	31,920	PS1m	$18,066,720
Q2m	33,600	PS2m	$17,359,705
EoDo	-1.44		
P1o	1,350	TR1o	$18,468,000
P2o	1,301	TR2o	$18,729,474
Q1o	13,680	PS1o	$6,716,880
Q2o	14,400	PS2o	$6,715,137
Export			
EoDm	-1.44		
P1m	1,300	TR1m	$20,384,000
P2m	1,300	TR2m	$20,384,000
Q1m	15,680	PS1m	$7,306,880
Q2m	15,680	PS2m	$7,306,880
EoDo	-1.44		
P1o	1,250	TR1o	$8,400,000
P2o	1,250	TR2o	$8,400,000
Q1o	6,720	PS1o	$2,963,520
Q2o	6,720	PS2o	$2,963,520
Processing			
P1m	30	TR1	$201,600
Q1m	6,720	PS1	-$1,135,680
P1o	30	TR1	$86,400
Q1o	2,880	PS1	-$486,720
Total			
TRm	$67,669,811		
TotalTRo	$27,129,474		
Total			
PSm	$23,530,905		
Total			
Pso	$9,191,937		
Total TR	$94,799,284		
Total PS	$32,722,842		

Scenario 5			
Premium			
EoDm	-0.8		
P1m	1,500	TR1m	$40,320,000
P2m	1,300	TR2m	$38,671,360
Q1m	26,880	PS1m	$15,214,080
Q2m	29,747	PS2m	$13,862,195
EoDo	-1.44		
P1o	1,350	TR1o	$15,552,000
P2o	1,250	TR2o	$15,936,000
Q1o	11,520	PS1o	$5,656,320
Q2o	12,749	PS2o	$5,622,221
Export			
EoDm	-1.44		
P1m	1,300	TR1m	$20,384,000
P2m	1,078	TR2m	$21,059,769
Q1m	15,680	PS1m	$7,306,880
Q2m	19,533	PS2m	$6,935,849
EoDo	-1.44		
P1o	1,250	TR1o	$8,400,000
P2o	1,037	TR2o	$8,678,476
Q1o	6,720	PS1o	$2,963,520
Q2o	8,371	PS2o	$2,798,937
Processing			
P1m	30	TR1	$201,600
Q1m	6,720	PS1	-$1,135,680
P1o	30	TR1	$86,400
Q1o	2,880	PS1	-$486,720
Total			
TRm	$59,932,729		
TotalTRo	$24,700,876		
Total			
PSm	$19,662,364		
Total			
Pso	$7,934,438		
Total TR	$84,633,605		
Total PS	$27,596,803		

Key to the calculation of scenarios

P1 (m/o)	Initial price paid for mandarin/other citrus
P2 (m/o)	Price paid after redistribution to remaining markers for mandarin/other citrus
Q1 (m/o)	Initial quantity sold of mandarin/ other citrus
Q2 (m/o)	Quantity sold after redistribution to remaining markers for mandarin/other citrus
EoD	Elasticity of demand
TR (m/o)	Total revenue for mandarin/ other citrus
PS (m/o)	Producer surplus for mandarin/ other citrus

Appendix 2: Scenarios description

This section briefly describes the method by which change in producer surplus was found for the five scenarios.

Scenario 1 assumes that the current market distribution of citrus will remain the same. Therefore there will be no change to prices, quantities or producer surplus for any market. This scenario will occur either because: the decision is made to extend ICA-28 to SA, WA and Tas, therefore making irrelevant the APVMA decision; or the decision from the APVMA is to allow post harvest use of dimethoate, therefore allowing the citrus industry to behave as normal. Producer surplus in this base scenario is $31.38 million.

Scenario 2 assumes that ICA-28 is extended to SA, and that the APVMA decision rules to disallow post-harvest dimethoate treatment for mandarins. Therefore there will need to be a redistribution of 1,680 tonnes of mandarins from WA and Tas to other markets. In this case the addition of 1,680 tonnes to the remaining domestic market for mandarins caused a decrease in price from $1,500/t to $1,401/t, and there is no change to the export or processing markets. Producer surplus falls by $1.66 million per year, compared to scenario 1.

Scenario 3 assumes that ICA-28 is extended to SA, and that the APVMA decision rules to disallow post-harvest dimethoate treatment for all citrus. Therefore there will need to be a redistribution of 1,680 tonnes of mandarins and 720 tonnes of other citrus from WA and Tasmania to other markets. In this case the 1,680 tonnes mandarin goes to the domestic market. The excess 720 tonnes of other citrus is redistributed to the remaining domestic market causing a decrease in domestic price from $1,350/t to $1,301/t. Producer surplus falls by $3.71 million per year, compared to scenario 1.

Scenario 4 assumes that ICA-28 is not extended to any other States, and that the APVMA decision rules to disallow post-harvest dimethoate treatment for mandarins. Therefore there will need to be a redistribution of 6,720 tonnes of mandarins from SA, WA and Tasmania to other markets. In this case the mandarins are redistributed to the remaining domestic market to the point where domestic price $1,500/t equals export price $1,300/t (2,867 tonnes). The remaining 3,853 tonnes of mandarins are then sold

on the export market, with a subsequent fall in price from $1,300/t to $1,078/t. Producer surplus falls by $5.53 million per year, compared to scenario 1.

Scenario 5 assumes that ICA-28 is not extended to any other States, and that the APVMA decision rules to disallow post-harvest dimethoate treatment for all citrus. Therefore there will need to be a redistribution of 6,720 tonnes of mandarins and 2,880 tonnes of other citrus from SA, WA and Tasmania to other markets. In this case the 6,720 tonnes of mandarin is redistributed to the domestic and export market as in scenario 4. The other citrus is redistributed to the remaining domestic market to the point where domestic price $1,350/t equals export price $1,250/t. Due to the relatively inelastic nature and smaller size of the remaining market for other citrus, this only accommodates 307 tonnes. The remaining 2,573 tonnes of other citrus is redistributed to the export market to the point where export price $1,250/t falls to $918/t (2720 tonnes). Producer surplus falls by $7.14 million per year, compared to scenario 1.

Appendix 3: State Contingent Analysis: Multi-period benefit

	Year	Best Case	Middle Case			Worst Case			Benefit of AWM	Probability that result of APVMA decision will apply
			None	Medium	High	None	Middle	High		
2004	1	0	0	0	0	0	0	0	0	0%
2005	2	0	0	0	0	0	0	0	0	0%
2006	3	0	0	0	0	0	0	0	0	0%
2007	4	0	0	-13,056	-14,092	0	62,172	71,392	106,416	5%
2008	5	0	0	-39,168	-42,276	0	186,517	214,176	319,249	15%
2009	6	0	0	-130,559	-140,921	0	621,724	713,920	1,064,163	50%
2010	7	0	0	-195,839	-211,382	0	932,586	1,070,880	1,596,245	75%
2011	8	0	0	-261,118	-281,842	0	1,243,448	1,427,839	2,128,327	100%
2012	9	0	0	-261,118	-281,842	0	1,243,448	1,427,839	2,128,327	100%
2013	10	0	0	-261,118	-281,842	0	1,243,448	1,427,839	2,128,327	100%
2014	11	0	0	-261,118	-281,842	0	1,243,448	1,427,839	2,128,327	100%

Appendix 4: Sensitivity Scenarios: probability

Scenario A

With AWM	Outcome of ICA Negotiations	Outcome of APVMA Decision			
		None	Medium	High	
	Best case	3%	8%	9%	20%
	Middle case	8%	20%	23%	50%
	Worst case	5%	12%	14%	30%
		15%	40%	45%	100%
			→	←	

Without AWM	Outcome of ICA Negotiations	Outcome of APVMA Decision			
		None	Medium	High	
	Best case	1%	2%	2%	5%
	Middle case	2%	6%	7%	15%
	Worst case	12%	32%	36%	80%
		15%	40%	45%	100%
			→	←	

Scenario B

With AWM	Outcome of ICA Negotiations	Outcome of APVMA Decision			
		None	Medium	High	
	Best case	2%	5%	4%	10% ↓
	Middle case	6%	18%	16%	40% ↓
	Worst case	8%	23%	20%	50% ↑
		15%	45%	40%	100%

Without AWM	Outcome of ICA Negotiations	Outcome of APVMA Decision			
		None	Medium	High	
	Best case	1%	2%	2%	5%
	Middle case	2%	7%	6%	15%
	Worst case	12%	36%	32%	80%
		15%	45%	40%	100%

Scenario C

With AWM	Outcome of ICA Negotiations	Outcome of APVMA Decision			
		None	Medium	High	
	Best case	5%	14%	12%	30% ↑
	Middle case	9%	27%	24%	60% ↑
	Worst case	2%	5%	4%	10% ↓
		15%	45%	40%	100%

Without AWM

	Outcome of ICA Negotiations	Outcome of APVMA Decision			
		None	Medium	High	
	Best case	1%	2%	2%	5%
	Middle case	2%	7%	6%	15%
	Worst case	12%	36%	32%	80%
		15%	45%	40%	100%