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Methyl Bromide usage and alternatives for disinfestation treatments

J Jobling; S Morris; H James
Sydney Postharvest Laboratory

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Level 1
50 Carrington Street
Sydney NSW 2000
Telephone: (02) 8295 2300
Fax: (02) 8295 2399
E-Mail: horticulture@horticulture.com.au

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Project Number AH01034

Methyl Bromide Usage and Alternatives for Disinfestation Treatments

Prepared by

Dr Jenny Jobling
Dr Stephen Morris
Ms Hannah James

Sydney Postharvest Laboratory
16 Julius Avenue
Riverside Corporate Park
Delhi Rd, North Ryde NSW 2113

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Executive Summary

There is no one alternative treatment for methyl bromide. The phytosanitary treatments of the future will involve a range of treatments and will vary on a country/product/pest basis.

The following recommendations are made for each of the project objectives -

1. *Carry out an assessment of the crops that require methyl bromide treatment for export clearance.*

   All of the crops discussed in this report require methyl bromide fumigation for some export markets (Table 1).

2. *Carry out an assessment of the crops that have alternatives to methyl bromide treatment.*

   All crops in this report have alternative treatments to methyl bromide (Table 1). These alternatives could be used for both export and interstate trade. However the feasibility of each treatment/crop combination varies considerably and is discussed in Section 3 on a per crop basis.

   Most treatment/crop combinations do not have alternative export protocols approved for Australian markets or commercial infrastructure in place to carry out the treatment on a large scale.

3. *Carry out an assessment of crops that have alternatives that have not been adopted by industry.*

   Most of the industries discussed continue to use methyl bromide as the new protocols are more difficult or risky to use. The citrus and mango industries are the main users of alternative treatments and this change was market driven.

   Successful implementation of any alternative treatments is limited by
   - Often difficult and slow negotiate of export protocols for country/product/pest combinations between Australia and the importing country.

   - Considerable work is required to produce sufficient data to satisfy importing countries that the alternative treatment is commercially viable and of a quarantine standard.

   There is a need for a Market Access co-ordinator. This position should oversee the whole process from innovative research, to production of efficacy data for the new treatment and finally assist with the export protocol negotiation process through the Horticulture Market Access Committee, Biosecurity Australia and AQIS.

   It is important that the protocols offered for negotiation through the Market Access Committee are the minimal necessary to achieve the required level of phytosanitary efficacy and that they have a clause addressing the correction of minor breaches. In the past approved protocols have been too rigid and offer no options for minor breaches.

A central database of all work done to date would be useful. A lot of Market Access data has been developed over the years. A range of funding bodies has funded the work. A central database of all the work would be a useful reference source for future research work and Market Access negotiations.

4. *Assess crops that don't have alternatives to methyl bromide.*

All crops have alternative treatments. These treatments can however be improved by reducing the treatment duration. This may be achieved by combining treatments. However combination treatments make the negotiation of new export protocols more complex and difficult to regulate.

5. *Recommendations for the most cost effective research on alternatives for methyl bromide for each commodity.*

These recommendations have been marked in Table 1. These recommendations are conditional on current market needs and industry investment.

It is difficult to recommend the most cost/effective alternative as this often depends on the level of industry or commercial investment in infrastructure.

6. *Make recommendations on what Institutes/researchers should be considered for different types of research (based on their experience/skill base/resources).*

The development of an alternative quarantine treatment can be summarised in the following flow chart -

Development of new treatment (1)

Test efficacy and aim for minimum chemical residue

↓

Negotiate acceptability of new treatment with target market

↓

Current Treatment (2)

Assess target market acceptance of treatment

↓

Collection of efficacy data for protocol negotiation

↓

Protocol negotiation through the Horticulture Market Access Committee and Biosecurity Australia.

↓

Commercial or Industry investment in infrastructure

↓

Commercial uptake of the alternative treatment

Following on from the flow chart the allocation of research projects could be determined by the following criteria.

1) For new treatments and protocols -
These projects aim to develop new technology that has not been implemented before on horticultural crops or new treatment/crop combinations. The outcomes will be medium to long term.

These projects should be open to all researchers with submissions being selected on their merits. A lot of this preliminary innovative research will be done outside the current main quarantine protocol development laboratories, at other Institutes and Universities.

It will be necessary at other stages for these projects to be collaborative with the main laboratories that have active insect colonies in the later stages.

2) Development of quarantine protocol data for known treatment/crop combinations -
These projects aim to rigorously assess the efficacy of alternative treatments currently approved for horticultural crops in other countries. They also aim to collect data which satisfies the requirements for export protocol negotiation between Australia and the importing country. The outcomes from these projects will be short to medium term.

There are three main labs with fruit fly colonies that do most of the data gathering for protocol development;
Queensland Department of Primary Industries (Qld DPI), Cairns
New South Wales Department of Agriculture (NSW Dept. Ag.), Gosford and
Agriculture Western Australia (Ag. WA), Perth.

The main laboratories also have obvious geographic areas of research speciality. In the past QLD DPI has concentrated on work with tropical crops, the Southern states with temperate crops and WA on work with Mediterranean fruit fly. It is likely that this geographic delimitation will remain in the future.

For quarantine pests other than fruit flies, other laboratories with the necessary entomological expertise with that pest as well as the necessary horticultural expertise may be required to do the work.

Any future funding of any work aimed at gathering data for an export protocol should be closely reviewed to ensure the methodology is correct for the target market. The development of a research manual similar to the NZ or Japanese guidelines may be useful to ensure the correct experimental procedure is followed for this type of research (MAFF, 1994).

For the three main laboratories with fruit fly colonies there is an issue of continuity of funding for colony maintenance. Short-term projects do not guarantee the on going up keep of the valuable colonies. These colonies are a critical resource for successful development of quarantine protocols for Australia.

These colonies should be maintained by internal budgets and possibly some matching

Horticulture Australia Limited (HAL) funds. HAL could lobby respective Departments to make this a priority.

An annual or bi-annual workshop for all Market Access researchers would also be beneficial in an effort to improve communication and ensure there is no overlap of research.

7. *Make recommendations on what research has the potential to provide the greatest return on an across-horticulture basis.*

   The following recommendations have been based on the current level of industry and commercial investment in the alternative treatment technology. A cost/benefit analysis is required for each treatment as the success largely depends on the level of investment in scaling up the alternative treatments to a commercially useful size.

   The following treatment/crop combinations are recommended to have the potential to provide the greatest return on an across-horticulture basis.

Crop	**Alternative Treatment**	**Benefits**
Apples and pears	Cold (fruit fly only) Cold + CA (fruit fly plus other pests)	Facilities are available and export markets are expanding
Berry fruit	Area freedom	Areas of freedom could be expanded
Nuts – Chestnuts Macadamia nuts	Fumigants – pyrethrum ethyl formate phosphine	Not fruit fly hosts Can develop fumigants for other crops
Cut flowers	Fumigants – pyrethrum ethyl formate phosphine	Large export industry
Grapes	Cold treatment	Facilities available
Mango	Heat treatment	Large export market relative to other tropical crops and provides an opportunity to develop infrastructure
Stone fruit	Low temperature + CA	Large export market and very dependent on methyl bromide
Temperate vegetables	Fumigants – pyrethrum ethyl formate phosphine	Not fruit fly hosts. Large export potential

The following treatments seem to have the greatest across industries benefit.

1. *Heat treatments* – for tropical crops where the target pest is fruit fly. What heat treatment is used across these crops will largely depend on a cost/benefit analysis and commercial investment.

2. *Cold storage or cold storage plus CA* – for temperate crops and citrus where light brown apple moth, coddling moth or fruit fly are the target insects.

3. *Fumigants* – such as pyrethrums or ethyl formate for leafy vegetables, flowers and nuts which are not fruit fly hosts and need fumigation against surface insects.

More work is needed to determine the benefits of phosphine as there is some evidence to suggest that this fumigant damages many crops with the long dose times at warm temperatures. Phosphine research fits into the new research category as discussed earlier.

Irradiation also has potential for many crops but the major hurdles for that technology is commercial investment in infrastructure and approval from importing countries.

Area freedom and possibly the 'Winter Window' concept also have potential to expand as an alternative treatment. They are chemical free options and the success of other crops could be transferred to other crops, avocadoes for example.

Project Objectives

1. Assessment of the crops that require methyl bromide treatment for export clearance

2. Assessment of crops that have alternatives to methyl bromide treatment

3. Assessment of crops that have alternatives that have not been adopted by industry

4. Assess crops that don't have alternatives to methyl bromide

5. Recommendations for the most cost effective research on alternatives for methyl bromide for each commodity.

6. Make recommendations on what Institutes/researchers should be considered for different types of research (based on their experience/skill base/resources).

7. Make recommendations on what research has the potential to provide the greatest return on an across-horticulture basis.

Project methodology

The information for this project was collected from a range of sources. This included a detailed search of the scientific literature, books and relevant reports, consultation with researchers and Government representatives.

Data for export requirements was found on the AQIS website and for inter state trade information was obtained from the respective Departments of Agriculture. A list of references is included with this report for further information.

Table 1. Recommendations for Alternatives to Methyl Bromide for Horticultural Crops and their Major Quarantine Pests.
Treatments marked with an * are the recommended treatment for that crop based on demonstrable or probable efficacy and estimated commercial viability.

Product	Currently require methyl bromide	Most promising alternative	Details	Availability of Alternatives
Apple	Y	*Cold CA + heat + cold Irradiation	0 to 4°C for 12 to 22 days 0.4% O_2 + 5% CO_2 at 20°C for 22.5 h 0°C for 54 – 154 days	USDA approved for Qld fruit fly Cold + CA available but not approved in Australia
Avocado	Y	Carbonyl sulfide *Area freedom	1% carbonyl sulfide for 7 h and 2% carbonyl sulfide for < 4 h at 25°C (Chen *et al*., 1998)	Area freedom (approved Australia to NZ)
Berry fruit	Y	*Area freedom Systems approach Cold + CA	Tasmania	Area freedom approved (Strawberries from Australia to Japan)
Cherry	Y	*Low O_2 + Low temp Irradiation	0.25% O_2 at 0°C for 40 days	In-transit cold (approved Taiwan)
Chestnut	Y	Pyrethrum Ethyl formate Phosphine	 300 – 400 gm/m^3 for 48 – 72 hr	Alternative fumigants not yet registered
Citrus	Y	*Cold (need more flexible protocols) Area freedom	0, 0.6, 1.1, 1.7 or 2.2°C for 10, 11, 12, 14 or 16 days	Cold treatment (approved USA) Cold treatment (approved Indonesia) Area freedom approved lemon and limes (Approved to Japan)
Custard apple	Y	Vapour heat Irradiation		
Cut flowers	Y	Cold - tolerant species Insecticide dip, Systems approach *Fumigants	0 – 1°C for 8 – 13 days Malathion + cabaryl dip for 30s Pest monitoring, field spray + dip Ethyl formate, pyrethrum, phosphine	Insecticide dips and fumigants available but not approved for export

Table 1 continued. Recommendations for Alternatives to Methyl Bromide for Horticultural Crops and their Major Quarantine Pests.
Treatments marked with an * are the recommended treatment for that crop based on demonstrable or probable efficacy and estimated commercial viability.

Product	Currently require methyl bromide	Most promising alternative	Details	Availability of Alternatives
Fresh stone fruit Nectarine Peaches Plums	Y Y Y Y	*Cold Low O_2 + low temp Irradiation	0 – 3°C for 18 – 22 days 0°C for 12 days 0.25% O_2 for 20 days at 0°C 0.25% O_2 for 40 days at 0°C 0.24% O_2 for 14 days at 5°C 0°C for 12 – 21 days 0.25% O_2 for 40 days at 0°C	Cold available (approved in Taiwan and USA for some countries)
Grapes	Y	*Cold Fumigants Irradiation	0°C – 2°C for 13 – 22 days Ethyl formate, pyrethrum, phosphine	Cold available but not approved
Macadamia nut	Y	*Fumigants Irradiation	Ethyl formate, pyrethrum, phosphine	Fumigants available but not approved
Mango	Y	*VH, *HTFA Irradiation	Seed 46.5°C for 10 min Seed 46.5°C for 10 min	Vapour heat treatment (approved Japan and USA for some countries)
Melon	Y	*Vapour Heat Area freedom	 Winter window	 Area freedom approved NZ
Nashi fruit	Y	*CA + Low temp Irradiation Phosphine	0.25% O_2 at 0°C for 14 days	Cold + CA available but not approved
Nuts - general	Y	*CA + cold *Fumigants Irradiation	0.4% O_2 for 6 days at 10°C Ethyl formate, pyrethrum, phosphine	Cold available but not approved, long treatment time

Table 1 continued. Recommendations for Alternatives to Methyl Bromide for Horticultural Crops and their Major Quarantine Pests.
Treatments marked with an * are the recommended treatment for that crop based on demonstrable or probable efficacy and estimated commercial viability.

Product	Currently require methyl bromide	Most promising alternative	Details	Availability of Alternatives
Other tropical fruit Guava Carambola Lychees Loquat	Y Y Y Y Y	*Vapour heat Cold, VH, VH + cold Cold Cold	46°C for 10 mins (varies with crop) 1.1°C for 15 days 46°C for 35+ min Centre 46.2°C and then 2°C for 42 h as for citrus 6°C for 23 days	Heat treatments are approved in USA for some countries/crops
Papaya	Y	*VH, HTFA Cold	44.5°C for 8.75 hours 0 – 4°C for 10 – 16 days	Heat treatments are approved in USA for some countries
Pear	Y	*Cold storage Heat + CA + Cold Irradiation	0 to 4°C for 12 to 22 days	USDA approved for Qld fruit fly Cold + CA available but not approved in Australia
Persimmon	Y	Cold Area freedom Irradiation	As for citrus	Cold treatment is approved in USA for some countries.
Strawberry	Y	Low O_2 + low temp *Systems/Area freedom Irradiation	0.25% O_2 for 10 days at 0°C Tasmania	Cold available but not approved Area freedom approved for Japan
Tropical Vegetables ^ Temperate Vegetables	Y	*VH Cold Area freedom Fumigants Irradiation	46°C for 10 mins (varies with crop) 0 to 2°C for 10 to 22 days Ethyl formate, pyrethrum, phosphine	Heat treatments are approved in USA for some countries/crops Cold available (approved Taiwan) Area freedom (approved NZ)

^ bitter melon, eggplant, pepper, squash (zucchini), and tomato.

1. Introduction

It is the role of international, national and state authorities to ensure that systems are in place, underpinned by sound legislation, operational protocols and product treatments that will minimise or prevent the movement of pests and diseases across quarantine boundaries.

Trade in horticultural products is dependent upon effective quarantine procedures that prevent the accidental introduction of exotic pests and diseases in imported countries. An important aspect of this process is the use of postharvest disinfestation treatments against pests. Treatment may be either pre-shipment, in-transit or as an emergency treatment on arrival when it is observed that specified phytosanitary requirements have not been met (Corcoran, 2001).

Post-entry quarantine is heavily dependent on the use of the fumigant methyl bromide. The availability of methyl bromide may be restricted after 2005, the date some uses are to be phased out as set down by the Montreal Protocol. It is unlikely that new chemical alternatives will become available for either pre-shipment or post-entry use by 2005 (Corcoran, 2001).

Physical treatments such as cold, heat, irradiation and atmosphere modification have been widely researched in the laboratory and in some cases are used successfully as pre-shipment quarantine treatments. However, the scaling up of these treatments to handle high volumes of product needs to be done to ensure these treatments are commercially viable.

New disinfestation treatments also need approval from importing countries usually on a country-by-country; product-by-product and sometimes cultivar-by-cultivar basis (Chaplin, 2001).

1.1 Australian export markets

Traditionally the Australian export industry has focused on markets that have few access barriers, like Hong Kong and Singapore. In more recent years Australia's position in the Asian market come under pressure with competition from other suppliers. This increased competition means that Australia is keen to expand its export opportunities into other markets, particularly the more difficult countries like Japan, Taiwan and Korea where quarantine restrictions are stricter. Market access to these countries with strict quarantine procedures requires a substantial commitment for their development.

One of the difficulties for market access research is that market opportunities change from year to year but disinfestation research and market access negotiations take many years. The registration of new technologies may be easier if they are developed by a number of countries seeking access, rather than one country acting alone and this is usually the case (McEvilly, 2001).

Even within Australia there are market access regulations for the movement of plant material between insect, or disease affected areas into clean areas. There is an Interstate Certification Assurance scheme (ICA) where growers can become accredited within their own state in order to send products inter state. This scheme means that there must be an audited record system to ensure traceability and treatment verification for the treated product.

The food safety and environment standards have recently become far more sophisticated and accountable for quarantine treatments. This is in response to an increased environmental and health awareness by consumers. The market chain can therefore expect to have to comply with regular audits and surveillance by appropriate authorities in an effort to maintain the strict food safety and environment standards (Hocking, 2001). The increase in demand for "clean" food will also encourage growers and exporters to develop non-chemical alternative quarantine treatments. The non-chemical treatments developed can be used for both export and inter state trade.

1.2 Market access protocol development

The development of new export protocols is a long and involved process. The Horticultural Market Access Committee (HMAC) was an initiative of the Australian Horticultural Corporation during the mid 1990's. It was formed to prioritise market access requests for government negotiators. Horticultural products represented on the committee include citrus, apples, pears, stone fruit, cherries, vegetables and macadamia nuts. These products account for over 80% of horticultural exports to global markets (Kellaway, 2001).

HMAC endorses market access proposal from industries, which can demonstrate that a long-term sustainable export trade will result from attainment of market access. The committee believes that this trade potential should be demonstrated before significant resources are expended (Harris, 2001).

Plant Biosecurity Australia (BA) was established in October 2000 as a policy group within the Department of Agriculture, Fisheries and Forestry Australia (AFFA).BA's main responsibility is to negotiate with overseas plant protection organisations to determine conditions for Australian products and particularly the removal of unjustifiable phytosanitary barriers to trade (Harris, 2001). Negotiating access to new markets is a lengthy process involving many steps, and often takes from four to ten years to complete.

1. 3 Developing non-chemical alternatives

There are many non-chemical disinfestation treatments currently available. There are two main hurdles for these new technologies;

1. Establishing new export protocols for the replacement to methyl bromide
2. Commercially developing the new technology as a viable step in the export chain.

One of the most important steps is negotiating new protocols with the importing country and this can take several years. As the threat of methyl bromide becomes a reality then this negotiation process needs to be speeded up.

There has been a lot of work done around the world into alternative disinfestation treatments as the threat of losing methyl bromide has been looming for many years. New research may be required to adapt existing protocols already available, to new crops and to establish new efficacy data for export protocol negotiations. The recommended alternatives for the crops reviewed appear in Table 1.

Many of the recommended treatments require substantial capital investment and this can be the stumbling block as many commodities have short seasons and so the cost recovery is slow. The other issue is that many industries are spread over wide geographical areas and so a central facility is not always commercially feasible.

1.4. Hurdles for introducing alternative treatments

It is likely that the new treatments will need to be done at central facilities as they will have to be accredited and audited to ensure they satisfy the requirements of the importing country.

This may help to overcome the difficulties for growers/packers trying to implement new disinfestation procedures, as growers are concerned that they rely on casual employees with limited skills or training.

Packers and growers are also reluctant to meet the additional operational difficulties in supplying a market that requires disinfestation treatments and phytosanitary clearance. This is because these treatments involve additional work, increased costs and increased risk of damaging the product. The increased returns must therefore justify the risks before new treatments will be implemented (Witcombe, 2001).

The Horticultural Industries are in desperate need of a disinfestation process that is easily applied commercially within the minimum time at minimum cost. Ideally the treatment should not require a chemical input to ensure its long-term sustainability and it should not damage the product (Walker, 2001). Most crops do have non-chemical alternatives. Unfortunately the new treatment schedule will be dependent on product/insect/country combinations for export protocols. The simple, "across the board" disinfestation schedule with methyl bromide is unlikely to be replaced.

References:

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2001. Gosford NSW. p 34 - 37.

McEvilly, G. (2001). Forward. Australian Disinfestation Workshop 24/25 July 2001. Gosford NSW. p 4.

Walker, P. (2001). Shortcomings in disinfestation practices and future needs. Australian Disinfestation Workshop 24/25 July 2001. Gosford NSW. p 10 – 16.

Witcombe, R. (2001). Markets and research needs for the future, products and access impediments. Australian Disinfestation Workshop 24/25 July 2001. Gosford NSW. p 7 – 9.

2. Potential Methyl Bromide Alternative Disinfestation Treatments

The alternative disinfestation treatments described below are mainly for pre-shipment disinfestation treatments. There are few options for post-entry quarantine where live insects are found in or on imported products (Chaplin, 2001). Phosphine or pyrethrum fumigation could be alternatives for post-entry quarantine. A major problem for the use of phosphine is the treatment time, as fumigation is 3 – 5 days at ambient temperatures, which is much longer than methyl bromide treatment, and many products can be damaged by the treatment (Table 2.1).

There will be no one alternative treatment to cover all perishable products; each product will have to be addressed on a crop by crop basis. Although it may be possible to group products into classes based either on target insects or their sensitivity to chilling injury for example and a corresponding quarantine treatment.

Work in progress in Australia and overseas shows that combining treatments such as cold, heat and low oxygen or high CO_2 levels shortens the treatment period without damaging the fruit. The individual treatments described below may therefore be more effective in combination (De Lima, 2001). However, combination treatments of perishable products have, up to now, been rarely reported. This is probably due to the extensive technical documentation required for their inclusion in an export protocol (Bell *et al.*, 1998).

It is important to note that some importers ask that disinfestation research follow formal experimental procedures. Japan for example, have standard methodologies (MAFF, 1985, 1987) and New Zealand have strict experimental protocols as well (MAF, 1994). Disinfestation researchers in Australia apply similar procedures to their research for access to other countries and other fruit fly free regions (Jessup, 2001). This is important, as sound scientific data is required when export protocols are negotiated.

2.1 Cold treatment

Target organism: Tropical and sub tropical flies

The exposure of citrus fruits to temperatures near the lower limit for normal metabolism eg. 1°C for 14-16 days is an effective control for both Queensland and Mediterranean fruit fly. However, cold treatments are generally not as suitable for tropical and subtropical fruits as they are more susceptible to chilling injury. Injury occurs when products are exposed to temperatures below 12-15°C. The symptoms of chilling injury vary and may be either internal or external or both. Such injury often renders the product unmarketable. Hence cold treatment is not a viable disinfestation treatment option for tropical and subtropical fruits.

Cold disinfestation treatments, particularly for citrus, take a minimum of 14 days (at 0°C, longer at warmer temperatures). It is beneficial if the treatment can be done in transit rather than on shore. Treatment on shore means a considerable loss of shelf life for the product. A short shelf life on arrival can result in heavy losses as the product can't hold up during marketing on arrival.

The use of sustained cold temperature as a means for insect control has been employed for many years. Rigid adherence to specific temperatures and time periods effectively eliminates certain insect infestations. Treatments may be conducted in refrigerated compartments of transporting vessels or in containers cooled by the ship's refrigeration system or by individually refrigerated containers. Guidelines for the USA can be found in the following document USDA (1996), PPQ Treatment Manual guidelines (in transit cold treatment of containerized cargo), Section III, Part 10 and Section IV Part 4.

Approved disinfestation treatments for citrus are a combination of temperature and time and are country and pest specific.

0.0°C (32°F) for 13 days
0.6°C (33°F) for 14 days
1.1°C (34°F) for 18 days
1.7°C (35°F) for 20 days
2.2°C (36°F) for 22 days

For citrus going to Japan the in-transit cold-treatment requires that a fruit pulp temperature of minus 0.6 ± 0.6°C be maintained for a minimum uninterrupted exposure time of 12 days. The guidelines for Japan and Korea are variety specific and do not allow time and temperature combinations. These inflexible protocols should be renegotiated to be similar to the US guidelines.

Treatment must be done in approved vessels, containers or cold storage warehouses. The USDA has approved this treatment for a range of product/pest/country combinations. The main products it is approved for include citrus, pear, stone fruit, apple, kiwifruit, carambola, loquats, papaya, quince and pomegrante (USDA, 2001).

Benefits:

- Already approved for use on citrus
- Fruit fly eggs and larvae are killed by exposure to temperatures of 10°C or less
- Relatively easy to apply and no residues
- Possibility to improve treatment with combine CA + cold

Potential Problems:

- Long treatment times shortens shelf life and increases export risk
- Causes damage in chilling sensitive products eg. Tropicals
- On shore disinfestaion makes some markets inaccessible
- In-transit protocols are difficult to maintain
- Some protocols are too complicated eg. Taiwan, should be renegotiated

Possible alternative for the following crops:

Citrus	Apples and pears	Stone fruit	Nuts
Flowers	Persimmon	Carambola	Loquat
Mangosteen	Grapes	Kiwifruit	Temperate vegetables

Countries where this method is used:

Canada	Europe	Israel	Jordan
Mexico	Morocco	South Africa	Chile
USA			

2.2 Heat treatment

Target organisms: Fruit flies, lepidoptera (codling moth) and fungi

Heat disinfestation treatments have been developed over many years for both tropical and subtropical fruit products. Several countries currently employ these treatments and they enable trade previously restricted by quarantine bans. Commercial treatments are in place in Australia for mangoes and are being developed for other tropical fruit and cucurbits.

Heat treatments against fruit fly are required to bring the core temperature of the largest fruit in the coolest part of the treatment chamber to the specified temperature and hold it for the required treatment time. At temperatures above 45°C insect pests die. The temperatures applied range from 40 to 50°C, the duration of the treatments from 10 minutes to 8 hours. Temperatures and the duration of the treatment must be very precise in order to kill the pests without damaging the commodity (Bell *et al.*, 1998).

Heat treatment has the advantage of providing a short time (5 h), no chemicals residues and heat treatment is relatively cheap (Corcoran, 2001). However the margin for error between an effective heat treatment and product damage is very small and so considerable care is required to use these treatments commercially.

Recent research by the Qld DPI for the disinfestation of Qld fruit fly indicates that heat treatment times can be reduced up to 75% when a low oxygen atmosphere is applied for a short, targeted period during the treatment process (Corcoran, 2001).

Countries where this method is used:

Caribbean	Mexico	South America	Taiwan
USA			

2.2.1. Hot water immersion

The treatment involves large bins of fruit being immersed in tanks of hot water for a specified time at a specified temperature. Hot water immersion has the advantage of small capital costs and effectiveness when protocols are strictly adhered to. The USDA estimates the typical cost for a two-tank system to cost up to $200,000 USD to build (USDA, 2001). The figure quoted by Chaplin (2001) is < $25,000. The difference in cost is no doubt due to the sophistication and size of the units quoted.

This treatment has been tried on mangoes and papayas but there are problems due to fruit injury. Research to date indicates that hot water has a limited role as a disinfestation treatment (Jordan, 2001). The USDA has approved its use for mealy bugs and other surface pests on limes, lychee and mango (USDA, 2001).

Variations on a hot water immersion include;

warm soapy water and brushing for durian and breadfruit
soapy water and wax for cherimoya and passionfruit (USDA, 2001).

Hot water immersion is not recommended for grapefruit, stonefruit, or carambolas (Hallman, 1991).

Benefits:

- Low cost compared to vapour heat treatent
- Short treatment time
- Effective against a range of surface "armoured" insects

Potential Problems:

- Most products are damaged by hot water
- Difficult to adopt in a commercial situation

Possible alternative for the following crops:

Papaya	Guava	Vegetables in combination with cold	Bulbs
Tubers	Mangoes	Cut flowers	

2.2.2. *Vapor heat treatment (VHT).*

The main limiting factor in the adoption of vapor heat treatment is the high cost, currently in excess of US$1 million per unit. However the Japanese have developed very efficient VHT units are in commercial use.

The USDA has approved vapour heat treatment for bell pepper, some citrus, eggplant, mango, papaya, pineapple, squash, tomato and zucchini. The treatment for most products is 44.4°C (112°F) for 8.75 hours and then cool immediately. They recommend that commodities be exposed to 44.4°C (112°F) to determine tolerance to the treatment before commercial shipments are attempted (USDA, 2001).

Benefits:

- Widely accepted as a quarantine treatment for tropical fruit
- Also effective against other insects
- Less damaging than hot water

Potential Problems:

- Margin for product damage is small, must use good quality product
- Expensive

Possible alternative for the following crops:

Mangoes	Bitter melon	Eggplant	Pepper
Squash	Tomato	Carambola	Lychee
Citrus	Papaya	Pineapples	Zucchini
Sweet Cherries	Custard apple	Melon	

2.2.3 High temperature forced air (HTFA)

The high temperature forced air system is a lower cost version of vapor heat treatment. The commercial success of this disinfestation treatment verifies it as a legitimate alternative to methyl bromide. This system overcomes the problem of water condensing on the surface causing damage, which can occur in the VHT. In the HTFA system conditions are controlled to prevent condensation occurring. The treatment times for the HTFA are longer than for VHT but the units are about 30% of the cost of the VHT.

The United States has approved HTFA treatment for citrus, mango and papaya (USDA, 2001).

Benefits:

- Accepted as an alternative quarantine treatment
- Cheaper than VHT (about 30% cheaper)
- Overcomes the problem of condensation damage due to VHT

Potential Problems:

- Treatment times are longer
- Margin for error or variability is small
- Not suitable for all crops – avocado, lychee and nectarine.

Possible alternative for the following crops:

Papaya	Carambola	Mango	Citrus
Persimmons			

2.2.4 Low cost heat treatment

Developed in Australia and currently undergoing commercialisation, low cost heat treatment arose out of the need for an affordable heat disinfestation system. It is suitable for farm level use and provides a significantly lower cost than vapor heat treatment or high temperature forced air.

Benefits:

- Low cost compared to VHT or HTFA
- Suitable for on farm use

Potential Problems:

- Low margin for error or variability must use good quality fruit

Possible alternative for the following crops:

Papaya	Carambola	Mango

2.3 Irradiation

Target organisms: Fruit flies and fruit weevils

There is a substantial amount of scientific literature, developed over the last forty years, to support the safety of food irradiation. The technology has been used in Australia and New Zealand for many years to sterilise medical products, bandages, dressings and cosmetics ingredients and for a range of quarantine purposes such as to prevent seeds sprouting and to kill pests in non-food products. (http://www.anzfa.gov.au)

Various forms of irradiation technology have been investigated as disinfestation treatments over the last 50 years. The advantage of irradiation is that the treatment is fast, residue-free and fruit can be treated in the final package. However, capital costs are high which means treatments must be done in a few central locations (Corcoran, 2001).

The treatment dose for fruit flies is 75 – 150 Gy but for other insects such as moths they require a dose of ~ 250 Gy (Corcoran, 2001). The USA has proposed 150 – 250 Gy for fruit flies and 100Gy for mango seed weevil. At these doses the insects are not killed but will not develop to the next life stage or the adults are sterile (Morris and Jessup, 1994).

Systems that use the radioisotope, cobolt-60 have received variable acceptance around the world due to concerns about radioactivity. Steritech® is an Australian company that uses gamma irradiation with cobalt-60 as the radiation source. This treatment is widely used for sterilising medical supplies and there are plants in Sydney and Melbourne.

Electron beam technology offered an alternative form of irradiation that offers the advantage of being environmentally friendly. However, it does not penetrate as well as cobolt-60 and fruit would have to be fed through the irradiator on a belt before being packed. Examples of this technology include Surebeam® that uses x-ray and electron beam technology and is used in the USA to disinfest tropical fruit from Hawaii.

Other kinds of irradiation, such as microwave technology, have been investigated but have not proven to be technologically effective. Irradiation has so far failed to become significantly established as a disinfestation treatment although if no other non-chemical alternatives to methyl bromide are found it may be that irradiation is the only alternative treatment (Daysh., 2001). In the USA the Food and Drug Administration approved the use of irradiation as a phytosanitary measure for fruit and vegetables in 1986. There are currently no approvals in Australia for the irradiation of food. Although Steritech Pty Ltd has sought approval from the Australia New Zealand Food Authority (ANZFA) for a variation from ANZFA Standard A-17 Irradiation of Food to allow for the irradiation of nuts, oilseeds, herbs and spices and teas for reasons related to disinfection, disinfestation, sprout inhibition and weed control. A recent press release from Surebeam Corporation outlines a proposal to develop an x-ray facility in Northern Australia for tropical fruit exports to New Zealand. This facility would also allow export of fruit to other countries where irradiation has been approved.

There are a number of factors influencing the expanding use of irradiation of food, including:

- consumer acceptance of the technology, USA particularly;
- a demand by consumers to reduce chemical residues in food
- food security, especially in some developing countries and countries that
- experience large losses of food from spoilage organisms and pathogens; and
- increasing concerns about food borne illness and its impacts.

The Steritech application to ENZFA can be found on the ENZFA web page. http://www.anzfa.gov.au/foodstandards/recentstandardsdevelopment/applications/applicationa413irradiationofherbsandspices/applicationa413preli983.cfm.

There is also more information on the International Consultative Group of Food Irradiation's web page (http://www.iaea.org/icgfi/).

The USDA has approved irradiation treatment for abiu, atemoya, carambola, longan, lychee, papaya, rambutan, and sapodilla from Hawaii (USDA, 2001).

Benefits:

- Rapid process
- Completely effective at proper doses
- Sealed packages and containers can be treated effectively
- New x-ray technology is safer than using a radioactive isotope.

Potential Problems:

- Consumer acceptance of irradiation safety is low
- Treatment needs to be approved by many countries
- Expensive
- Must be done in a central location
- The size of the plants is small and so suits high value low volume crops

Possible alternative for the following crops:

Mango	Papaya	Mangosteen	Rambutan
Lychee	Guava	Kiwi fruit	Onion
Potato	Asparagus	Cabbage	Cauliflower
Tomato	Cut flowers	Grapes	Melons
Vegetables			

Countries where this method is used:

This treatment is registered in about 35 countries.

2.4 Insecticidal dips and in-line flood sprays

Target organisms: Fruit fly and other surface insects

New insecticides are being developed that target physiological systems specific to insects and thus some have low mammalian toxicity. These newer chemicals (the neonicotinoids, lactone glycosides, phenyl pyrazoles and insect growth regulators) have not been seriously investigated as chemical disinfestation alternatives. Newer chemicals do not have the cost advantage as older products and there are likely to be consumer issues relating to synthetic chemical residues in food (Corcoran, 2001).

Treatments using insecticides such as Fenthion and Dimethoate are used to disinfest a number of horticultural products in Australia for both interstate trade and export. However, these treatments are becoming unacceptable and it is likely that the Codex Alimentarius Commission will eventually delist these insecticides. Therefore, such treatments do not provide a sustainable option as an alternative to methyl bromide. However in a situation where there is no non-chemical alternative these chemical treatments may be warrant further investigation (Corcoran, 2001).

Benefits:

- Effective, readily available
- Relatively cheap and easy to apply

Potential Problems:

- Push to reduce chemical use – dimethoate is likely to be banned
- Problems with chemical residues
- Efficacy depends on contact with the insect which is difficult in cracks
- Potential health risk for users

Possible alternative for the following crops:

Flowers	Interstate citrus

Countries where this method is used:

Australia	Hawaii	Thailand	Zimbabwe

2.5 Pyrethrum sprays

Target organisms: surface insects, don't control fruit flies

Synthetic pyrethroids have both a repellent and protective activity. They are very effective against a broad range of insects. However they have a low toxicity to other animals and are regarded as an environmentally friendly alternative to synthetic insecticides. Unfortunately pyrethrum doesn't control Queensland fruit fly and so its use would be for non-fruit fly host products such as cut flowers. It is also important to get good penetration of the pyrethrum as it is only effective on contact with the insect. Research has found that when protea flowers are treated in an enclosed chamber for 12h with a combination of pyrethrin (Pestigas, CIG) and diclorvos (Insectigas, CIG), both propelled by CO_2, the combination is more efficacious that the gases used alone (Wood and Wood, 1991).

Benefits:

- Regarded as a safe chemical (GRAS, generally regarded as safe)
- Effective against a wide range of surface pests
- Short application time
- Relatively cheap to apply

Potential Problems:

- Doesn't control all insects eg. Qld Fruit Fly
- Must be used in combination with other treatments for 99.998% mortality
- Needs to be registered for postharvest application on fruit and vegetables

Possible alternative for the following crops:

Cut flowers	Leafy vegetables	Nuts

Countries where this method is used:

Australia	Malaysia	New Zealand

2.6 Controlled and modified atmospheres and combination treatments.

Target organisms: Lepidoptera, scale insects, thrips, aphids, beetles, fruit fly

Controlled atmosphere technology is a long accepted treatment for long-term storage of both apples and pears. Researches are currently investigating the use of modified atmospheres as a disinfestation treatment for various products. Although this treatment is unlikely to be successful in the control of fruit flies (Chaplin, 2001).

Modified atmosphere technology relies on the natural development of an altered atmosphere composition caused by respiration of fruit or vegetable product enclosed in polyethylene bags or other kinds of plastic film. Modified atmosphere conditions are subject to variation, while controlled atmosphere provides prescribed atmospheric conditions. The treatments are usually carried out at gas concentrations of 0.5% O_2 and 2.5% CO_2 and at low temperature (0 to 2°C) over at least 1 to 2 months (Bell *et al.*, 1998). If the oxygen concentration is lower then the treatment time can be shortened.

Combination treatments

Combination treatments of perishable products have, up to now, been rarely reported. This is probably due to the extensive technical documentation required (Bell *et al.*, 1998). However, combination treatments that debilitate and then kill the insect pests or eliminate the possibility of subsequent reproduction are the most likely to result in avoidance of damage to the commodity (Brecht, 1994).

Work at NSW Dept Agriculture, Gosford has shown some promising results for controlled or modified atmospheres in combination with heat against Queensland fruit fly in mandarins and lemons (Jessup *et al.*, 1998). A combination treatment has also been shown to be successful for codling moth in apples (Whiting *et al.*, 1999).

Examples	*Crop*	*Country*
Vapour heat + Cool storage	Lychee	Taiwan to Japan
Soapy water + Wax coating	Custard apple	Chile to USA

Benefits:

- Reduces the time required for heat and cold and so optimises shelf life
- Reduces the risk of product damage as treatment times are reduced
- Increases flexibility in marketing

Potential Problems:

- Products may not be tolerant to low O_2 and high temperatures required to kill insects
- CA facilities are expensive
- MAP is difficult to apply commercially
- Long treatment times for CA at low temperature

Possible alternative for the following crops:

Nuts	Apples	Pears	Nashi fruit
Stone fruit	Strawberry	Blue berries	Lettuce

Countries where this method is used:

Argentina	Brazil	Canada	Europe
USA			

2.7 Other Fumigants

Phosphine.

Phosphine is a fumigant that is widely used to treat stored grain and dried fruit. In the past, phosphine was generated from plates or tablets through their reaction with moisture in the air. Phosphine is now available in cylinders mixed with carbon dioxide (20 000 ppm) and is much safer and easier to apply (ECO$_2$FUME). Effective treatment against fruit flies require a treatment time of 2 to 3 days at concentrations of about 1200 ppm (Corcoran, 2001). Phosphine fumigation could also be done at very low concentrations (~ 50 ppm) over a treatment time of several weeks, perhaps in-transit. Phosphine is highly toxic and so its use would also pose some health and safety issues. The exposure threshold limit for an 8-hour per day exposure is 0.3ppm. The maximum concentration for a single exposure for animals should not exceed 50 ppm (USDA, 2001). However research has shown that when it is used properly it is safe to human health (Peterson, 2001).

Insect responses to phosphine are well documented for a wide range of species (Lindgren and Vincent, 1966, Seo *et al.*, 1979). Successful fumigation of tomatoes and grapefruit infested with Oriental, Mediterranean and Caribbean fruit flies has been reported as well as Australian wildflowers (Williams *et al.*, 2000; Weller and Graver, 1998). However, many products are damaged by phosphine fumigation and the USDA recommends that growing plants, cut flowers and greenery, fresh fruits and vegetables should not be treated with phosphine due to their low tolerance to the treatment (USDA, 2001).

To date phosphine has not been developed to a standard to permit registration for quarantine purposes with perishable commodities. Many companies are reluctant to make submissions for registration because of the high cost involved in meeting stringent tests for health and safety authorities. However registration of ECO_2Fume is under way in the US for use in the disinfestation of fresh products.

Benefits:

- Most likely fumigation alternative to methyl bromide
- Could be an option for point of entry fumigation for live insects
- Technology such as gas-tight tents used for grain could be adopted for fruit and vegetables.

Potential Problems:

- Long treatment time; 3 – 5 days for treatment of fruit fly at high temperature (23 to 24°C)
- Not 100% mortality and so may need to be part of a systems approach
- Unknown phytotoxicity for fresh products
- Requires a high degree of gas tightness for treatment and so existing EDB facilities could not be used unless upgraded
- Highly corrosive – could not be done in shipping containers
- Potential for insect resistance if not used and contained carefully
- Consumer and importing government approval of its use

Possible Alternative for the Following Crops:

Citrus – grapefruit Tomatoes Cut flowers

Carbonyl sulfide.

Tests conducted by Obenland *et al.* (1998) showed that fruit flies needed to be fumigated for 8 hours or more to be controlled. However these exposure times also caused damage to the rind of lemons. There is potential may be potential to use this fumigant in combination with some other treatments so that the exposure time can be reduced.

Hydrogen cyanide

Target organisms: Thrips, white flies, scale insects and aphids

This treatment is a highly toxic gas and is not approved in all countries. There is also poor acceptance of this treatment by consumers. It is however used in Japan.

Ethyl formate

Target organisms: external pests, aphids, mealy bugs, western flower thrips

Ethyl formate has a long history as a fumigant. It has been used on tabacoo, cereals, and dried fruits. The advantage of ethyl formate is its ease of application, its favourable toxicological and environmental properties although it is flammable which creates practical problems. There is potential for ethyl formate use in grain. There is also potential for this fumigant for fresh produce to kill external pests. The toxicity of ethyl formate has been shown to be higher if it is mixed with 10% carbon dioxide. The CO2 mixture also reduces the flammability risk of pure ethyl formate. This fumigant is not currently registered for use on fresh produce.

Methyl iodide

Research by the USDA in California has shown that methyliodide fumigation with proper aeration was found to be effective in eradicating pests with minimum injury to lemons and nectarines (Aunh *et al.*, 2000).

Sulfuryl flouride

Some research has shown that sulfuryl flouride may be an alternative to methyl bromide. The product is called Vikane® and is marketed by Dow chemicals as a household fumigant for termites and cockroaches. Dow chemicals have applied for tolerances to be set for the use of sulfuryl fluoride on a range of fresh and grain products (ranging from 0.1 to 6ppm depending on the product). The tolerance of the products to the treatment will need to be investigated as well as the mortality of the target pest.

2.8 System Approaches

Target Organism: Different pests and diseases

A systems approach is "the integration of different pest risk management measures, at least two of which act independently, and which cumulatively achieve the desired level of phytosanitary protection" (Lloyd, 2001). A systems approach decreases pest pressure to a level that is very easily controlled (Bell *et al.*, 1998).

This approach involves monitoring the pest infestation levels throughout the growing and marketing of the product. It cannot be assessed using the Probit 9 mortality tests but instead relies on he probability of one or more mating pairs in a shipment or on the maximum pest limit MPL. This method has been investigated for shipping citrus from Qld to Victoria. Citrus is a poor fruit fly host and is grown in the winter when fruit fly populations are low and so it is possible to send fruit fly free shipments from monitored areas (Lloyd, 2001).

Research in the USA has also shown that this the systems approach is a viable, cost effective alternative to controlling codling moths in apples and cherries for export to Japan and Korea and negotiations are continuing to get these countries to accept this approach (Moffitt, 1994).

Benefits:

- Demonstrated to be effective on citrus for interstate trade
- Pest monitoring throughout production improves quality
- Adoption of IPM and reduced chemical use

Potential Problems:

- Not accepted as a quarantine treatment for export
- Field monitoring can be costly

Possible alternative for the following crops:

Citrus	Blueberries	Apple	Banana
Cherries	Papaya	Avocado	

Countries where this method is used:

Argentina	Brazil	Mexico	New Zealand
South Korea	USA		

2.9 Possible Future Quarantine Treatments

These treatments currently provide little benefit as quarantine treatments. However it is important to know what has been trialed overseas so that the research is not duplicated in Australia.

Fruit Coatings

Coatings work by acting as a modified atmosphere, reducing the level of oxygen inside the fruit while raising the level of carbon dioxide. The younger the fruit fly the easier it is to kill inside a coated fruit. The insecticidal effect of coatings is enhanced by heated air and pesticide dips. Fruit coatings have some potential as a combination treatment (Hallman, 2001).

Radio Frequency Coatings

Radio frequency was noted to kill insects 70 years ago. This treatment is more effective for dry commodities than fresh ones. The water in fresh products heats up during the treatment and this can cause damage to the product. Work is continuing in Washington State on this treatment for disinfestation (Hallman, 2001).

High Pressure

High pressure (also known as ultra-high pressure; 40 – 1,000 MPa) is used commercially to deactivate enzymes and microorganisms in order to prolong the shelf life of foods. This would only be a treatment option for processed foods.

Other options

Other possible treatments suggested include Ohmic heating, pulsed electric fields, oscillating magnetic fields, ultrasound and ultraviolet light most of these really only have potential against surface pests.

2.10 Pest-free Zone

Target organism: Mediterranean fruit fly (*Ceratitis capitata*), melon and fruit flies

This is where production is in an officially recognised zone that is free from quarantine pests. This allows commodities to be exported without quarantine treatment (Bell *et al.*, 1998).

Currently, some countries with quarantine restrictions for fruit flies accept area freedom for Tasmania and the mainland areas in the Riverland, Riverina and Sunraysia. However, other countries, including Japan and Taiwan, accept area freedom for Tasmania only (Harris, 2001). Because of changes to trapping regimes following the papaya fruit fly incursions, Biosecurity Australia was required to send detailed submissions overseas this year. The negotiations for market access are therefore on going.

Benefits:

- Demonstrated to be effective on citrus in Australia
- Pest monitoring throughout production improves quality
- Adoption of IPM and reduced chemical use
- Non chemical treatment increases consumer acceptability

Potential Problems:

- Maintaining pest-free areas involves strict controls
- Field monitoring can be costly

Possible alternative for the following crops:

Grapes Kiwifruit Melon Citrus
Vegetables

Countries where this method is used:

Australia	Brazil	Chile	China
Ecuador	Japan	Mexico	New Zealand
USA			

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2.1 Summary Table (from Paull and Armstrong, 1994)

R = treatment registered against certain pests
A = possible alternative treatment
I = likely host intolerance based on passed information
Blanks = no information available

Commodity	Methyl Bromide	Phosphine	Other Fumigants	Cold Treatment	Heat Treatment	Modified Atmospheres	Radiation	Systems	Combination
Almonds	R	R		A	A	R	A		
Apple	R	I		R		A	A	A	
Apricot	R	I		R			A		R (Cold + MB)
Avocado	I				A		I		R (Cold + MB)
Banana	I	I		I	A				A (Certification)
Carambola				A	I				
Cherry	R	I		R			A		R (Cold + MB)
Cucumber	R				R (VH)				
Date	R	R		R		R	A		
Eggplant	R	I			R (VH)				R (Dimethoate)
Fig, fresh									
Flowers	R		A (HCN)	A	A		I		
Grapefruit		A							
Grapes	R			R				R	R (Cold + MB)
Kiwifruit				R					
Lemon	R			R					
Litchi	I			A	A				
Macadamia	A	A							
Mandarin	R						R		
Mango	R	I			A		A		

2.1 Summary Table cont. (from Paull and Armstrong, 1994)

R = treatment registered against certain pests
A = possible alternative treatment
I = likely host intolerance based on passed information
Blanks = no information available

Commodity	Methyl Bromide	Phosphine	Other Fumigants	Cold Treatment	Heat Treatment	Modified Atmospheres	Radiation	Systems	Combination
Melons	R				R (VH)				
Nectarine	R	I		R			A		R (Cold + MB)
Orange	R			R			A	A	
Papaya	A	I		A	R		A		A (hot water + cooling)
Peach	R	I		R			A		R (Cold + MB)
Pear	R	I		R		A	A		
Pecan	A	A							
Pepper	R	I			R (VH)				R (Dimethoate)
Persimmon				R					
Pistachio	A	A							
Plum	R	I		R			A		R (Cold + MB)
Pomegranate				R					
Strawberry	R	I			I		A		
Tomato	R	I			R (VH)				R (Dimethoate)
Walnut	R	R		A	A	R	A		

3.0 Potential Alternative Treatments for Specific Crops

3.1 APPLES

Target Pests: Light brown apple moth, codling moth, fruit fly

Apples are Australia's third largest exported fruit crop with 33,711 tonnes being exported in 1999/2000. None of Australia's top three exporting destinations for apples have restrictions for fruit fly.

Export and production data

Crop	Total Production Volume (tonnes)	Total Volume Exported (tonnes)	Total Volume Exported (%)	Top Three Export Markets	Market Volume (tonnes)	Market Volume (%)	Fruit Fly Free Required (y/n)
Apples	334,353	33,711	10.08	Malaysia	9,400	27.88	n
				Singapore	6,931	20.56	n
				Sri Lanka	3,657	10.85	n

* Data from The Australian Horticultural Statistics Handbook 2000 – 2001 and from AQIS web page.

Export market quarantine information

Malaysia:
Phytosanitary Certificates for plant products that are hosts of Khapra beetle from infested countries. Even with valid phytosanitary documents, produce will be inspected at checkpoints to ensure that no post-treatment infestation has occurred.

Singapore:
An Import Permit is required for all plant material imported by air and all propagating material. A Phytosanitary Certificate is required for all plant material.

Sri Lanka:
All plant materials should enter the country under a permit previously issued by the Director of Agriculture. The import of fresh fruits requires a licence in a prescribed form issued by the Director of Agriculture or by an authorised officer of the Department of Agriculture, who shall specify the terms and conditions under which such licence is issued. All plant materials entering the country should be covered by a valid Phytosanitary Certificate, issued within 14 days before despatch of the consignment. An Additional Declaration as required in the permit.

Current treatment

Methyl Bromide + Cold Treatment

Alternative treatments

Irradiation with gamma radiation has proven to be an effective treatment for apples infested with fruit fly. Apples irradiated with gamma radiation doses of 25, 50, 75 and 100 Gy at 1048 Gy per hour showed no emergence of adult fruit fly (*Anastrepha frateculus*) at any of the doses tested (Arthur, V. *et al.* 1996). Radiation provides an alternative to fumigation with methyl bromide however it is not currently registered for use on most food products in Australia.

Cold treatment is already registered for fruit fly control on infested apples in Australia. Apples infested with larvae and eggs of *Ceratitis capitata* and stored at 0.5°C for 14 days or 1.5°C for 16 days showed no survivors and no fruit injury (Sproul, A.N., 1976). This indicates that the treatment is adequate to meet export requirements to obtain entry to quarantine areas (Sproul, A.N., 1976). The details for the treatment are in the USDA treatment manual (T107-d for Queensland fruit fly). The treatment schedule is 0 to 4°C for 12 to 22 days.

Combination treatments often reduce the amount of time that each treatment requires and this reduces the risk of damage to the fruit. Apples infested with Brownheaded leafroller, *Ctenopseustis obliquana,* and lightbrown apple moth, *Epiphyas postvittana*, exposed to a high-temperature controlled atmosphere of 2% O_2 and 5%CO_2 at 40°C for 8 hours combined with cold storage (0°C for 7 weeks) resulted in complete kill (Whiting, D.C. *et al.*, 1999).

Treatment	Advantages	Disadvantages
Irradiation	Rapid and effective	Expensive, low consumer acceptance.
Cold Storage	Already registered for use on apples, easy to apply and no residues	Long treatment time, risk of chilling injury
High Temperature Controlled Atmosphere + Cold Storage	Reduced treatment time increases shelf life	Complex method, and documentation difficult

Recommendations

There are several alternative treatments for apples.

- The treatment that is easiest to implement is cold storage (USDA treatment manual T107-d – 0 to 4°C for 13 to 22 days).
- Treatment times may be reduced by developing a combination treatment of heat, CA + cold. CA facilities are available and there are no obstacles for consumer acceptability for these non-chemical treatments.
- Irradiation is also a possibility. Work needs to be done to register the treatment and to determine the tolerance of apple varieties to this treatment.

- Phosphine and other fumigants may also be a possible alternative for apples

3.2 AVOCADOS

Target pests: Fruit fly, surface insects

Avocados are Australia's twenty-first largest exported fruit crop with 129 tonnes being exported in 1999/2000. Of the top three markets that Australia exports avocados to, New Zealand is the only one with a specific restriction to fruit fly.

Export and production data

Crop	Total Production Volume (tonnes)	Total Volume Exported (tonnes)	Total Volume Exported (%)	Top Three Export Markets	Market Volume (tonnes)	Market Volume (%)	Fruit Fly Free Required (y/n)
Avocado	24,311	129	0.53	New Zealand	55	42.64	y
				Singapore	44	34.11	n
				Hong Kong	9	7.21	n

* Data from The Australian Horticultural Statistics Handbook 2000 – 2001 and from AQIS web page.

Export market quarantine information

New Zealand:
Phytosanitary Certificate and Additional Declaration required. New Zealand prohibits the import of fruit fly host material from Australia unless it has been suitably treated in accordance with the Arrangement between the New Zealand Ministry of Agriculture and Forestry and the Australian Quarantine and Inspection Service concerning the access of host material of fruit fly species of economic significance into New Zealand from Australia.

For more information see appendix 1.

Singapore:
An Import Permit is required for all plant material imported by air and all propagating material. A Phytosanitary Certificate is required for all plant material.

Hong Kong:
Plants, Import Permits and Phytosanitary Certificiates must be declared to the Customs and Excise Service on arrival.

Current treatment

Methyl Bromide plus cold

Alternative treatments

There is some possibility that there are avocado cultivars that are resistant and do not present a risk of spreading fruit fly, even without postharvest disinfestation treatment (Hennessey, M.L., *et al.*, 1995). This provides a promising alternative to methyl bromide for future plantations but does not provide a solution for those already existing.

Gamma radiation is not an alternative treatment for avocadoes as avocados have a low tolerance to the treatment (Moy, J.H., *et al.*, 1971).

Carbonyl sulfide may prove to be a viable alternative with avocados tolerating 25°C carbonyl sulfide at a concentration of 1% for 7 hours or at 2% for less than 4 hours. Carbonyl sulfide may therefore be suitable as a fumigant for surface insects of avocados (Chen, C.C., *et al.*, 1998).

Treatment	**Advantages**	**Disadvantages**
Area freedom	No chemical residues	Constant monitoring and management of area
Carbonyl sulfide	Short treatment time	Promotes fruit softening
Resistant cultivars	Do not require postharvest treatment	Not applicable for existing plantations

Recommendations

Avocadoes are not tolerant to many of the proposed alternative treatments. More research is required to determine a viable alternative treatment. Future research could focus on;

- Developing pest free areas or a systems approach for showing freedom from surface pests and fruit fly
- Carbonyl sulfide could be an alternative fumigant treatment

3.3 BERRY FRUITS (excluding strawberries)

Target Pests: Fruit fly, surface insects

Export and production data

Crop	Total Production Volume (tonnes)	Total Volume Exported (tonnes)	Total Volume Exported (%)	Top Three Export Markets	Market Volume (tonnes)	Market Volume (%)	Fruit Fly Free Required (y/n)
Berry fruits	1,964						

* Data from The Australian Horticultural Statistics Handbook 2000 – 2001 and from AQIS web page.

Export market quarantine information

Japan (strawberries) similar protocols could be negotiated for other berries:
Phytosanitary Certificate and Additional Declaration required.
1. Permitted export from Tasmania only. Prohibited export from all other States in Australia.
2. All fresh fruit and vegetable fruit-fly hosts are currently prohibited from mainland Australia.
Additional declaration: The produce has been produced and packed in Tasmania.

For more information see appendix 1.

Current treatment

Methyl bromide

Alternative treatments
Little research has been done on alternative treatments for berries. Area freedom for Tasmania is acceptable for strawberries to the Japanese market. This approach may be able to be expanded to other regions in Australia.

There is also a possibility of a low temperature and low oxygen treatment although the shelf life following treatment will be very short.

Irradiation may also be a possible treatment as the treatment time is short, although the tolerance of the fruit would have to be determined.

Recommendations

- Systems approach and area freedom as demonstrated for blue berries and strawberries.

- Cold plus CA may be a possible treatment for areas where the systems approach is not possible.

3.4 CHERRY

Target Pests: Fruit fly, surface insects

Cherries are Australia's sixteenth largest exported fruit crop with 555 tonnes being exported in 1999/2000. Of Australia's top three export markets, only Taiwan has specific fruit fly requirements for cherries.

Export and production data

Crop	Total Production Volume (tonnes)	Total Volume Exported (tonnes)	Total Volume Exported (%)	Top Three Export Markets	Market Volume (tonnes)	Market Volume (%)	Fruit Fly Free Required (y/n)
Cherry	6,020	555	9.22	Hong Kong	227	40.90	n
				Singapore	127	22.88	n
				Taiwan	103	18.56	y

* Data from The Australian Horticultural Statistics Handbook 2000 – 2001 and from AQIS web page.

Export market quarantine information

Hong Kong:
Plants, Import Permits and Phytosanitary Certificates must be declared to the Customs and Excise Service on arrival.

Singapore:
An Import Permit is required for all plant material imported by air and all propagating material. A Phytosanitary Certificate is required for all plant material.

Taiwan:
Phytosanitary Certificate and Additional Declaration required. Separate Additional Declarations required for Tasmania and the Mainland States. To prevent the infestation of airfreight consignments of mainland commodities after fruit fly disinfestation and airfreight consignments of commodities from Tasmania, the new requirements that must be complied with from 1 September are (a) that all vented cartons of fruit fly host commodities must have the vents screened with mesh of a diameter less 1.6mm; OR (b) the transfer of fruit from the place of treatment to the airport loading for export must be in a closed vehicle.

For more information see appendix 1.

Current treatment

Methyl Bromide fumigation at a rate of:
64 mg/m^3 and fruit temperatures of 6 – 12.5°C,
48 mg/m^3 and fruit temperature of 13 – 16.5°C
40 mg/m^3 at 17 – 20.6°C

32 mg/m^3 at 21°C and above. All with a 2 hour exposure period (Moffitt *et al.*, 1983).
Cold treatment
Methyl bromide plus cold treatment

Alternative treatments

Cherries irradiated with gamma radiation at a dose of 75 Gy at 26°C and 70% relative humidity provided security against eggs and larvae of *Dacus tryoni*, with doses of 300-1000 Gy not affecting fruit quality (Jessup, 1990). Doses between 17.5 and 97 Gy have also been found to be effective quarantine treatments (Burditt, 1988).

Cold treatment is also a possible alternative as it is registered by the USDA as a treatment for cherries from Mexico (Treatment manual T107-b) against Mexican fruit fly. The treatment is 0 – 2°C for 18 – 22 days. The long treatment time reduces the shelf life of the fruit so an in-transit treatment may be possible to some markets.

Recommendations

- Cold plus low oxygen could be investigated
- Irradiation if approved for use in the importing country

3.5 CHESTNUTS

Target Pests: Surface insects

Export and production data

None of Australia's top three export markets require chestnuts to be fruit fly free.

Crop	Total Production Volume (tonnes)	Total Volume Exported (tonnes)	Total Volume Exported (%)	Top Three Export Markets	Market Volume (tonnes)	Market Volume (%)	Fruit Fly Free Required (y/n)
Chestnut	331	5	1.60	Japan	3.9	73.58	n
				Singapore	1.3	24.53	n
				Sri Lanka	0.1	1.89	n

* Data from The Australian Horticultural Statistics Handbook 2000 – 2001 and from AQIS web page.

Export market quarantine information

Japan:
All plants and plant products which serve as hosts of injurious insects or pathogens unknown or of restricted occurrence in Japan; living insects and pathogens; soil and

plants with soil, unless these are covered by a special Import Permit (only for experiment and research purposes).

Singapore:
An Import Permit is required for all plant material imported by air and all propagating material. A Phytosanitary Certificate is required for all plant material.

Sri Lanka:
All plant materials should enter the country under a permit previously issued by the Director of Agriculture. The import of fresh fruits requires a licence in a prescribed form issued by the Director of Agriculture or by an authorised officer of the Department of Agriculture, who shall specify the terms and conditions under which such licence is issued. All plant materials entering the country should be covered by a valid Phytosanitary Certificate, issued within 14 days before dispatch of the consignment. An Additional Declaration as required in the permit.

Current treatment

Surface insects are treated with insecticide dips.

Alternative treatments

The use of food irradiation is considered as a possible alternative to the fumigation of nuts in Brazil (Wiendl, F.M. *et al.*, 1986).

Ethyl formate dosages of 300-400 gm/m3 in an exposure period of 48-72 hours controlled all stages of insects (Muthu, M. *et al.*, 1983). Large scale disinfestation has been carried out on nuts (Muthu, M. *et al.*, 1983).

Treatment	**Advantages**	**Disadvantages**
Pyrethrum	No residue, GRAS chemical	Only kills surface pests
Phosphine	Relative short treatment time, used in grains	Some OH&S issues
Ethyl formate	Ease of application	Flammable, OH&S issues
Irradiation	Rapid and effective	Expensive and low consumer acceptance

Recommendations

Further research is required for chestnuts. Possible alternative treatments could include the following, although they are not currently registered for use on chestnuts.

- Ethyl formate fumigation

- Phoshine fumigation
- Pyrethrum sprays
- Irradiation

3.6 CUSTARD APPLES

Target Pests: Fruit fly, surface insects

Export and production data

None of Australia's top three export markets require custard apples to be fruit fly free.

Crop	Total Production Volume (tonnes)	Total Volume Exported (tonnes)	Total Volume Exported (%)	Top Three Export Markets	Market Volume (tonnes)	Market Volume (%)	Fruit Fly Free Required (y/n)
Custard apple	2,547	103	4.04	Hong Kong Singapore United Arab Emirates	67.0 30.0 4.1	65.05 29.13 3.98	n n n

* Data from The Australian Horticultural Statistics Handbook 2000 – 2001 and from AQIS web page.

Export market quarantine information

Hong Kong:
Plants, Import Permits and Phytosanitary Certificates must be declared to the Customs and Excise Service on arrival.

Singapore:
An Import Permit is required for all plant material imported by air and all propagating material. A Phytosanitary Certificate is required for all plant material.

United Arab Emirates:
All plant and plant products exported to United Arab Emirates must comply with Halal, whether certified as Halal or not. Imported and exported plants and products are subject to inspection. If they do not conform to plant quarantine regulations and law, the consignment is subject to return or destruction.

Current treatment

The current export markets for custard apples require phytosanitary clearance for surface insects. The current markets do not require treatment for Queensland fruit fly.

Alternative treatments

The USDA registered alternative treatment for custard apples is soapy water and wax (Treatment manual T102-b). This treatment is for Chilean false spider mite. The treatment requires a 20 second immersion in soapy water followed by a high pressure rinse and then immersion in a fruit wax for 30 seconds. The wax coating must cover the entire surface of the fruit.

Recommendations

- More research is required for custard apples. Immersion may be an alternative for surface insects but further treatments may be required if Queensland fruit fly is deemed a problem in other markets.

Possible alternatives could include;

- Vapour heat treatment
- Irradiation

3.7 CUT FLOWERS

Target pests: Surface insects

Export and production data

None of Australia's top three export markets require cut flowers to be fruit fly free.

Crop	Total Production Volume (tonnes)	Total Volume Exported (tonnes)	Total Volume Exported (%)	Top Three Export Markets	Market Volume (tonnes)	Market Volume (%)	Fruit Fly Free Required (y/n)
Cut flowers		55,151		Japan	28,999	52.58	n
				USA	10,040	18.20	n
				Netherlands	6,416	11.63	n

* Data from The Australian Horticultural Statistics Handbook 2000 – 2001 and from AQIS web page.

Export market quarantine information

Japan:
All plants and plant products which serve as hosts of injurious insects or pathogens unknown or of restricted occurrence in Japan; living insects and pathogens; soil and plants with soil, unless these are covered by a special Import Permit (only for experiment and research purposes).

USA:
An Import Permit is required for a large range of restricted articles including propagative materials (except articles for food, analytical, medicinal or manufacturing purposes), fruits, vegetables, etc.

Netherlands:
Phytosanitary Certificate required.

Current treatment

Methyl Bromide

Alternative treatments

Many alternative treatments have been tested on cut flowers. There are many species within this category and so no one treatment is effective for all flowers. For example tropical flowers are chilling sensitive whereas a cold treatment could be a possible treatment for some long life temperate flowers. Each treatment should be assessed as a product/country/pest combination.

Fumigation with other chemicals may be an alternative to methyl bromide. Phosphine is a less phytotoxic fumigant than methyl bromide, carbonyl sulfide, hydrogen cyanide or ethyl formate (Weller, G.L., *et al.*, 1998). Increased dosages tested against Protea 'Pink Ice' showed damage at dosages above 1 g/m3 for 5 hours, however levels observed for 1 g/m3 for 15 hours were still within marketable limits (Weller, G.L., *et al.*, 1998). At the highest dose, phosphine did not kill all life stages of psocids (*Liposcelis bostrichophilia*), non-diapausing two spotted mite (*Tetranychus urticae*), cotton whiteflt Type B (*Bemisia tabaci*) and rice weevils (*Sitophilus oryzae*) and ants (*Iridomyrex purpureus*) (Weller, G.L., *et al.*, 1998). This means that phosphine does not provide adequate control as a single treatment, it should be combined with other treatments to achieve complete kill (Weller, G.L., *et al.*, 1998).

Other researchers suggest a systems approach to keep flowers free of surface insects. This approach in combination with a postharvest treatment can be 100% effective (Paull and Armstrong, 1994).

Recommendations

There are many possible alternative treatments for cut flowers. However more research is needed to determine the optimum treatment/pest/species combination. Alternative treatments could include;

- Systems approach and field management - need to develop field management documentation.
- Pyrethrum sprays – environmentally friendly, need to determine efficacy
- Insecticidal dips- Effective and readily available but may not be sustainable.
- Irradiation - research required to determine species tolerance.
- Hot water dips or cold storage - research required to check species tolerance.

3.8 GRAPES

Target Pests: Fruit fly surface insects

Grapes are Australia's second largest exported fruit with 35,129 tonnes being exported in 1999/2000. None of Australia's top three export markets requires grapes be fruit fly free.

Export and production data

Crop	Total Production Volume (tonnes)	Total Volume Exported (tonnes)	Total Volume Exported (%)	Top Three Export Markets	Market Volume (tonnes)	Market Volume (%)	Fruit Fly Free Required (y/n)
Grapes	1,265,535	35,129	2.78	Hong Kong	11,279	32.11	n
				Singapore	9,718	27.66	n
				Malaysia	4,306	12.26	n

* Data from The Australian Horticultural Statistics Handbook 2000 – 2001 and from AQIS web page.

Export market quarantine information

Hong Kong:
Plants, Import Permits and Phytosanitary certificates must be declared to the Customs and Excise Service on arrival.

Singapore:
An Import Permit is required for all plant material imported by air and all propagating material. A Phytosanitary certificate is required for all plant material.

Malaysia:
Phytosanitary certificates for plant products that are hosts of Khapra beetle from infested countries. Even with valid phytosanitary documents, produce will be inspected at checkpoints to ensure that no post-treatment infestation has occurred.

Current treatment

The USDA currently allows Australian grapes that are treated with methyl bromide plus refrigeration (Treatment Manual T108). New Zealand allows the entry of Australian grapes that receive the same cold disinfestation schedules used to disinfest citrus of fruit flies.

Alternative treatments

There is little work reported in the literature for grapes. However the use of cold disinfestation either on shore or in-transit would be a suitable alternative.

Research evaluating new fumigants or irradiation may also provide alternative treatments that require a shorter treatment time. Research at the University of California Davis has had some success using ethyl formate fumigation for table grapes. The concentration used was between 26 and 160ppm for 1 to 3 hours at ambient conditions. Fumigation in combination with 10% CO_2 seems to improve the efficacy of the treatment (Vapormate, BOC gases).

Recommendations

- Cold disinfestation treatments either on shore or in-transit.
- More work needs to be done with other fumigants (Ethyl formate, phosphine and pyrethrum)
- Irradiation may be an alternative if grapes are tolerant to the treatment.

3.9 LEMONS/LIMES

Target pests: fruit and surface insects

Lemons/Limes are Australia's ninth largest exported fruit crop with 4,390 tonnes being exported in 1999/2000. Of the top three export markets, only Japan has specific fruit fly requirements.

Export and production data

Crop	Total Production Volume (tonnes)	Total Volume Exported (tonnes)	Total Volume Exported (%)	Top Three Export Markets	Market Volume (tonnes)	Market Volume (%)	Fruit Fly Free Required (y/n)
Lemons/Limes	29,293	4,390	14.99	Japan	2,908	66.24	y
				Hong Kong	817	18.61	n
				Singapore	301	6.86	n

* Data from The Australian Horticultural Statistics Handbook 2000 – 2001 and from AQIS web page.

Export market quarantine information

Japan:

Phytosanitary Certificate and Additional Declaration required. The citrus fruits covered by this certificate are apparently free from Mediterranean fruit fly and Queensland fruit fly. For more information see appendix 1.

Hong Kong:

Plants, Import Permits and Phytosanitary Certificiates must be declared to the Customs and Excise Service on arrival.

Singapore:

An Import Permit is required for all plant material imported by air and all propagating material. A Phytosanitary Certificate is required for all plant material.

Current treatment

Methyl Bromide

Cold Treatment

Alternative treatments

Gamma radiation treatments have been evaluated for citrus. Irradiation was applied at 0.049-0.047 kGy/min, alone and in combination with cold treatments and a synergistic effect was observed when the treatments were applied together (Ohta, A.T. *et al.*, 1989). Infested oranges stored for 14-21 days at 5.5 deg C required a radiation dose of 0.30 kGy or less to result in negligible egg hatch. Shortened durations of cold treatment required higher radiation dosages to achieve similar mortality rates (Ohta, A.T. *et al.*, 1989).

Lemons required higher doses of irradiation than oranges (Ohta, A.T. *et al.*, 1989). Irradiation treatment of citrus for fruit flies may be feasible since doses will be in the range 75-150 Gy (Corcoran, R.J., 2001).

Insecticide dips have also been used. Dimethoate dipping involves the full immersion of fruit in a dip containing 400mg/L dimethoate for one minute and dimethoate flood spraying entails flood spraying the fruit with a mixture containing 400mg/L at an application rate of 16L/min per square metre of the area being flood sprayed providing complete coverage of the fruit for 10 seconds after which the fruit must remain wet for 60 seconds (Hocking, D.F., 2001). This treatments achieved a 99.6% level of efficiency in hosts of Queensland fruit fly (*Dracus tryoni*) (Hocking, D.F., 2001).

Phosphine may also be a possible alternative treatment is the only fumigant other than methyl bromide that is registered for postharvest disinfestation of food in Australia (Williams, P., 2001), it is a fumigant that is affective against fruit fly and requires a treatment time of 2 to 3 days at concentrations of 1200ppm (Corcoran, R.J., 2001).

Heat treatment for fruit fly disinfestation has been studied for control in citrus fruit (Schirra, M., 1999), heat treatments are effective against a range of insects including fruit fly (Corcoran, R.J., 2001). Hot air treatments provide promising, non-chemical alternatives for citrus (Corcoran, R.J., 2001). Radio frequency heating can be faster with less total heat applied to the surface of the fruit, resulting in less surface damage, however radio frequency heating has never been commercially applied and is unlikely to be used on fresh produce due to it's higher moisture content (Hallman, G.J., 2001).

Fruit coatings have been shown to significantly reduce fruit fly infestation levels within fruits and they provide a possible future alternative (Hallman, G.J., 2001). Methods such as hot water, hot air, electromagnetic energy and combination treatments can also be used in citrus for the control of insect pests (Jordan, R.A., 2001).

Ethylene dibromide and methyl bromide are included as treatments into some countries (Pacific Island nations, Caribbean Island nations and Taiwan) (De Lima, 2001). However methyl bromide is phytotoxic to citrus.

Cold treatment is currently the main technology acceptable in international trade and, work done in Australia has resulted in market access for several citrus cultivars (DeLima, C.P.F., 2001). Cold treatment is the only registered alternative to methyl bromide for the disinfestation of citrus, the registered treatment is 1°C for 16 days and a more rapid alternative is desired (Williams, P. *et al.*, 1999), Combining other treatments may shorten the treatment period without damaging the product (DeLima, C.P.F., 2001).
Cold treatment is effective against Mediterranean fruit fly (*Ceratitis capitata*), however most fruit are chilling sensitive (Murata, T., 1990). Chilling injury in lemons subjected to cold disinfestations is unpredictable and difficult to formulate reproducible treatments for its alleviation (McLauchlan, R.L. *et al.*, 1995). Fruit treated with a 0.2 to 0.35% emulsion of sucrose fatty acid esters and stored at 1°C for a specified time showed reduced chilling-induced pitting (Murata, T., 1990).

Post harvest cold treatment: treatment commences when the core temperature of the produce reaches the specified temperature. Schedules range from 0 deg C for 14 days to 2.5 deg C for 22 days and are considered to have a 99.6% level of efficiency. (Hocking, D.F., 2001).

The main disadvantage of the cold treatment for citrus is that is does not suit all citrus from all climates in Australia. Losses are suffered from cold damage from fruit harvested from warmer climates. Cold treatment technology may be improved by a pre-treatment such as a short-term heat treatment for example hot water dips for 2 – 3 minutes at 52 – 53°C or hot water brushing for 20 seconds at 53°C which can both reduce chilling injury. There is also a trade-off between temperature and exposure time, different combinations suit different varieties of citrus.

Treatment	Advantages	Disadvantages
Cold treatment	Already approved for citrus, easy to apply and no residues.	Long treatment times reduce shelf life, risk of chilling injury.
Phosphine	Likely fumigation alternative to methyl bromide, option for point of entry fumigation for live insects.	Long treatment time, not 100% mortality. Highly corrosive.
Irradiation	Rapid and effective.	Expensive and low consumer acceptance.
Dimethoate dips and in-line flood sprays	Effective, cheap and readily available.	Problems with chemical reaidues, potential health risk for users.
Heat treatment	No residues, available for other crops	Costly

Recommendations

- Cold treatment with more work to increase the time/temperature limits and combinations.

  Registered cold treatments for export (De Lima, 2001):
  Exports to Japan: Lemons 14 days at 1.0 + 0.5°C.
  Exports to Korea: Lemons as approved for Japan.
  Export to USA: Using the USDA treatment schedule for other citrus (T107-d). A variation may be obtained providing the data is acceptable to the USDA.
  Other countries: In general all other countries have set treatments based either on the USDA treatment schedule or on the approvals given by Japan.

- Also need more negotiation for more flexible protocols for some countries.

- Irradiation is a possible alternative treatment although the tolerance of lemons and limes needs to be determined.

- Phosphine may also be a possible treatment although the tolerance of citrus to the treatment is unknown.

- Area freedom and systems approaches may also be an alternative for some production areas.

3.10 MACADAMIA NUTS

Target pests: Surface insects

Export and production data

None of Australia's export markets require that macadamias be free from fruit fly.

Crop	Total Production Volume (tonnes)	Total Volume Exported (tonnes)	Total Volume Exported (%)	Top Three Export Markets	Market Volume (tonnes)	Market Volume (%)	Fruit Fly Free Required (y/n)
Macadamia nut-in-shell	30,000	4,404	14.68	Hong Kong	2,075	47.12	n
				China	1,290	29.29	n
				Japan	18	0.41	n
kernel		5,972		USA	2,830	47.39	n
				Japan	976	16.34	n
				Belgium	713	11.94	n

* Data from The Australian Horticultural Statistics Handbook 2000 – 2001 and from AQIS web page.

Export market quarantine information

Nut-in-shell:

Hong Kong:
Plants, Import Permits and Phytosanitary Certificates must be declared to the Customs and Excise Service on arrival.

China:
Phytosanitary Certificates are required for all plants and unprocessed plant products.

Japan:
All plants and plant products which serve as hosts of injurious insects or pathogens unknown or of restricted occurrence in Japan; living insects and pathogens; soil and plants with soil, unless these are covered by a special Import Permit (only for experiment and research purposes).

Kernel:
USA:
Phytosanitary Certificate required. All nuts must be without fleshy or leathery husk.

Japan:
All plants and plant products which serve as hosts of injurious insects or pathogens unknown or of restricted occurrence in Japan; living insects and pathogens; soil and

plants with soil, unless these are covered by a special Import Permit (only for experiment and research purposes).

Belgium:
A Phytosanitary Certificate conforming to the model adopted by the International Plant Protection Convention, Rome, 1951 (as amended 1979). The official phytosanitary inspection in the exporting country on which the Phytosanitary Certificate is based must take place not more than 14 days before shipment. Official Verification's are considered met when the Phytosanitary Certificate is issued. Additional Declarations must not be added to the Phytosanitary Certificate. If a treatment of the plant or plant product is required, the details of that treatment will be entered on the Phytosanitary Certificate.

Current treatment

Methyl Bromide

Alternative treatments

The use of food irradiation is considered as a possible alternative to the fumigation of nuts in Brazil and so is also a likely alternative treatment for nuts in Australia if the treatment is approved (Wiendl, F.M. *et al.*, 1986).

Ethyl formate is also another option with dosages of 300-400 gm/m3 in an exposure period of 48-72 hours controlled all stages of insects (Muthu, M. *et al.*, 1983). Large scale disinfestation with ethyl formate has been carried out on nuts (Muthu, M. *et al.*, 1983).

Recommendations

There are probably many possible treatments for macadamia nuts as they are not as susceptible to damage some other fresh products. However the following treatments are seen to be the most viable to implement;

- Fumigants – pyrethrum, ethyl formate and phsophine
- Cold storage
- Irradiation

3.11 MANDARINS

Target insects: Fruit fly and surface pests

Mandarins are Australia's fifth largest exported fruit crop with 15,730 tonnes being exported in 1999/2000. Two of Australia's top three export markets require that mandarins are fruit fly free.

Export and production data

Crop	Total Production Volume (tonnes)	Total Volume Exported (tonnes)	Total Volume Exported (%)	Top Three Export Markets	Market Volume (tonnes)	Market Volume (%)	Fruit Fly Free Required (y/n)
Mandarins	78,258	15,730	20.10	Hong Kong	3,371	21.43	n
				Indonesia	3,140	19.96	y
				USA	2,346	14.91	y

* Data from The Australian Horticultural Statistics Handbook 2000 – 2001 and from AQIS web page.

Export market quarantine information

Hong Kong:
Plants, Import Permits and Phytosanitary Certificates must be declared to the Customs and Excise Service on arrival.

Indonesia:
Phytosanitary Certificate and Additional Declaration required. For the purpose of certifying citrus to Indonesia, mealy bugs are to be classified as injurious pests and a 21 infested unit inspection tolerance on mealy bugs is now permitted for export of citrus to Indonesia. Indonesia prohibits the import of fruit fly host material from Australia unless it has been sourced from an area that Indonesia considers free from fruit fly or has been suitably treated. One of the treatment schedules below must be used for produce originating from areas not designated as free from fruit flies. Treatment is to be included on the Phytosanitary Certificate. For more information see appendix 1.

USA:
Import Permit, Phytosanitary Certificate and Additional Declaration required. Ony from: Riverland District of South Australia, Sunraysia district of Victoria and New South Wales and the Riverina district of New South Wales. All farms, packing plants and treatment facilities must be registered in accordance with USDA requirements. For more information see appendix 1.

Current treatment

Methyl Bromide
Cold Treatment: 1°C for 16 days (Williams, P. *et al.*, 1999)

Alternative treatments

Cold treatment is the most likely alternative treatment for citrus. Mandarin fruit were disinfested of Queensland fruit fly (*Bactrocera tryoni*) by cold treatment at 1°C for 16 days. The treatment had 100% mortality, this treatment efficacy meets all known international market requirements (Heather, N.W. *et al.*, 1996).

Cold treatment is also an alternative for disinfestation of citrus against Mediterranean fruit fly (*Ceratitis capitata*), however most citrus are chilling sensitive (Murata, T., 1990). Fruit treated with a 0.2 to 0.35% emulsion of sucrose fatty acid esters and stored at 1°C for a specified time showed significantly reduced chilling-induced pitting (Murata, T., 1990). Cold treatment is currently the main technology acceptable in international trade and, work done in Australia has resulted in market access for several citrus cultivars (DeLima, C.P.F., 2001).

Cold treatment is the only registered alternative to methyl bromide for the disinfestation of citrus (1°C for 16 days), a more rapid alternative is desirable (Williams, P. *et al.*, 1999). Combining other treatments may shorten the treatment period without damaging the product (DeLima, C.P.F., 2001). The main disadvantage of the cold treatment for citrus is that is does not suit all citrus from all climates in Australia. Losses are suffered from cold damage from fruit harvested from warmer climates. Coldtreatment may be improved by a pre-treatment such as a short-term heat treatment can reduce chilling injury (hot water dips for 2 – 3 minutes at 52 – 53°C or hot water brushing for 20 seconds at 53°C). There is also a trade-off between temperature and exposure time, different combinations suit different varieties of citrus.

Heat treatment for fruit fly disinfestation has also been studied for control in citrus fruit (Schirra, M., 1999). Heat treatments are effective against a range of insects including fruit fly (Corcoran, R.J., 2001). Radio frequency heating can be faster with less total heat applied to the surface of the fruit, resulting in less surface damage. Radio frequency heating has never been commercially applied and it is unlikely to be used on fresh produce due to higher moisture content; however it is a possible future quarantine treatment (Hallman, G.J., 2001).

Hot air treatments provide promising, non-chemical alternatives for citrus (Corcoran, R.J., 2001). However, degreened mandarins (cv. Dancy) subjected to high temperature (45, 46 or 48 deg C), moist, forced air treatment for 0-4 hours showed unacceptable phytotoxic symptoms when treated at 46 or 48°C (Shellie, K.C. *et al.*, 1993). Flavedo colour change, percentage juice yield, soluble solids concentration and flavor rating values for fruits heated at 45°C were statistically similar to untreated fruits (Shellie, K.C. *et al.*, 1993). Treatment for 3 or 4 hours and subsequent cooling was sufficient to kill 100% *Anastrepha ludens* larvae (Shellie, K.C. *et al.*, 1993). This is a possible alternative treatment as long as a time/temperature combination can be developed that does not damage the fruit.

Dimethoate is another treatment option. Dipping involves the full immersion of fruit in a dip containing 400mg/L dimethoate for one minute and dimethoate flood spraying entails flood spraying the fruit with a mixture containing 400mg/L at an application rate of 16L/min per square metre of the area being flood sprayed providing complete coverage of the fruit for 10 seconds after which the fruit must remain wet for 60 seconds (Hocking, D.F., 2001). Both of these treatments achieved a 99.6% level of efficiency in hosts of Queensland fruit fly (*Dracus tryoni*) (Hocking, D.F., 2001).

Phosphine is another possible alternative. Phosphine is the only fumigant other than methyl bromide that is registered for postharvest disinfestation of durable commodities and flowers in Australia (Williams, P., 2001). Phosphine is affective against fruit fly and requires a treatment time of 2 to 3 days at concentrations of 1200ppm (Corcoran, R.J., 2001). However this treatment needs to be tested on fresh produce and registered for use on perishable products.

Irradiation treatments of citrus for fruit flies is also feasible since doses will be in the range 75-150 Gy and are unlikely to cause damage to the product (Corcoran, R.J., 2001).

Fruit coatings have been shown to significantly reduce fruit fly infestation levels within fruits and are a possible future quarantine treatment (Hallman, G.J., 2001). Methods such as hot water, hot air, electromagnetic energy and combination treatments can be used in citrus for the control of insect pests (Jordan, R.A., 2001).

<u>Registered cold treatments for export (De Lima, 2001):</u>

Exports to Japan: Tangors, tangerines, mandarins and tangelos 16 days 1.0 + 0.5°C.
Export to USA: Using the USDA treatment schedule for oranges. A variation may be obtained providing the data is acceptable to the USDA.
Other countries: In general all other countries have set treatments based either on the USDA treatment schedule or on the approvals given by Japan.

Ethylene dibromide and methyl bromide are included as treatments into some countries (Pacific Island nations, Caribbean Island nations and Taiwan). However methyl bromide is phytotoxic to citrus.

Treatment	**Advantages**	**Disadvantages**
Cold treatment	Already approved for citrus, easy to apply and no residues.	Long treatment times reduce shelf life, risk of chilling injury.
High temperature moist forced air	Cheaper than vapour heat treatment.	Longer treatment time, small margin for error.
Heat treatment	Shorter treatment time than cold	Risk of product damage
Dimethoate dips and flood spraying	Effective, cheap and readily available.	Problems with chemical residues, potential health risk for users.
Phosphine	Likely fumigation alternative to methyl bromide, option for point of entry fumigation for live insects.	Long treatment time, not 100% mortality. Highly corrosive.

Recommendations

Possible alternative treatments for mandarins would include;

- Cold with a more flexible time/temperature schedule
- Heat treatment plus cold in order to reduce chilling injury
- Irradiation and research is needed to determine the tolerance of mandarins to this treatment
- Phosphine and research is needed to determine the tolerance of mandarins to this treatment
- Area freedom for some districts

3.12 MANGOES

Target pests: Fruit fly and surface insects

Mangoes are Australia's ninth largest exported fruit crop with 3,226 tonnes being exported in 1999/2000. Of Australia's top three export markets, only Japan requires mangoes to be fruit fly free.

Export and production data

Crop	Total Production Volume (tonnes)	Total Volume Exported (tonnes)	Total Volume Exported (%)	Top Three Export Markets	Market Volume (tonnes)	Market Volume (%)	Fruit Fly Free Required (y/n)
Mangoes	26,372	3,226	12.23	Singapore	1,107	34.31	n
				Hong Kong	1,067	33.08	n
				Japan	469	14.54	y

* Data from The Australian Horticultural Statistics Handbook 2000 – 2001 and from AQIS web page.

Export market quarantine information

Singapore:
An Import Permit is required for all plant material imported by air and all propagating material. A Phytosanitary Certificate is required for all plant material.

Hong Kong:
Plants, Import Permits and Phytosanitary Certificates must be declared to the Customs and Excise Service on arrival.

Japan:
Phytosanitary Certificate and Additional Declaration required. ONLY Kent, Keitt, Palmer, R2E2 and Kensington variety of mango are approved for export to Japan. Other varieties of mangoes are not permitted to be exported to Japan as data has not been provided by industry to support establishment of a treatment. Country of origin labeling is now required for all goods, including fresh fruits and vegetables. The fruit has been inspected in accordance with the procedures required in the arrangement between Australia and Japan for the access of mangoes and were found to be free of Mediterranean and Queensland fruit flies. For more information see appendix 1.

Current treatment

Methyl Bromide
Vapour Heat Treatment

Alternative treatments

Vapour heat treatment is accepted as a quarantine treatment for mangoes exported to Japan, however the treatment induced internal breakdown in the inner mesocarp of ripe fruits, incidence and severity of breakdown is related to growing area and maturity at harvest (Esguerra *et al.* 1990).

Hot water treatment is also an alternative to methyl bromide and it is an inexpensive alternative to vapour-heat treatments (Jacobi *et al.*, 1995). Immersion of fruit in water at a constant temperature of 46°C for 90 – 115 minutes was found to be effective for mango disinfestation (McGuire, 1991). Fruit given the same treatment but for 30 minutes so that the fruit core temperature reached 45°C was also found to be effective (Jacobi *et al.*, 1995). The hot water treatment may be combined with a forced air treatment at 46°C for 195 minutes or 48°C for 150 minutes, where the water temperature gradually rose to 48°C, the forced air treatment at 48°C is more effective than forced air at 46°C (McGuire, 1991). Cultivars immersed in water at 46.1°C for 90 minutes and refrigerated after 24 hours were not damaged and were suitable for export, some cultivars showed unacceptable levels of lenticel damage, while fruit that were refrigerated immediately after immersion displayed surface scald (Grove *et al.*, 1997).

The hot water treatment may also be phased; 36.5°C for 60 minutes plus 46.5°C for 43 minutes attained and maintained a seed core temperature of 46 – 46.5°C for 5-12 minutes (Nyanjage *et al.*, 1998). While immersion in hot water is an effective disinfestation treatment for mangoes, the fruit may be damaged by the process (Joyce and Shorter, 1994). Conditioning may reduce the amount of damage. Conditioning fruit (7 hour heat-up period to a 37°C core temperature maintained for at least 12 hours) showed less pulp injury on ripening following hot water treatment (core temperature of 47°C maintained for 25 minutes) (Joyce and Shorter, 1994). Conditioning for 8 hours or more resulted in less than 1% of fruit being damaged (Jacobi *et al.*, 1995). Immersion at a constant temperature of 46°C is recommended for the disinfestation of mangoes because it most effectively controls disease without reducing market quality (McGuire, 1991).

High humidity hot air is also another possible alternative treatment. Fruit are heated to a fruit core temperature of 46.5°C for 10 minutes. Mangoes treated this way showed no internal or external injury although late matured fruit had better quality after treatment and ripening (Jacobi *et al.*, 1995). Fruit that were treated with hot water for disease control were damaged by the hot air, high humidity treatment (Jacobi *et al.*, 1996).

The combined treatment of hot water (53°C for 5 minutes) plus vapour heat treatment (seed surface temperature of 47°C for 25 minutes) combined with continuous storage at 22°C resulted in the highest quality fruit and is recommended for air freight marketing (Jacobi and Giles, 1997).

Irradiation is also an option for mangoes. Mangoes treated with a dose of 0.5 kGy were free from live *Dacus dorsalis* (Manoto et al., 1987), while fruit fly eggs exposed to irradiation from a 60co source and exposed to 40 and 100 krad were prevented from developing into adults, no adults emerged from pupae at any dose (Thomas *et al*, 1975).

Treatment	Advantages	Disadvantages
Hot air plus hot water treatment	Short treatment time	Damage to fruit
Irradiation	Rapid and effective	Expensive and low consumer acceptance
High temperature forced air treatment	Less damage than hot water	Risk of damage, expensive
Vapour heat treatment	Less damaging than hot water	Small margin for product damage, expensive
Hot water treatment	Low cost, short treatment time	Risk of damage
Hot water treatment plus conditioning	Reduced damage to fruit from hot water treatment	Complex treatment

Recommendations

The most promising alternative treatments for mangoes are;

- Heat treatment and the type of treatment will depend on the cost/benefit of each system.

  Single stage high temperature forced air is registered by the USDA for mangoes from Mexico (Treatment Manual T103-c-1)

  Vapour heat is also registered by the USDA for mangoes from the Philippines and Mexico (Treatment Manual T106-1-1 and T106-d-1 46°C for 10 minutes)

  Hot water is registered by the USDA for mangoes (Treatment Manual T102-1 a range of sip schedules are out lined depending on the variety and country of origin.

- Irradiation is also a possible alternative depending on the tolerance of the fruit to the treatment.

3.13 MELONS

Target pests: Fruit fly and surface insects

Melons are Australia's sixth largest exported fruit crop with 12,616 tonnes being exported in 1999/2000. Of Australia's top three export destinations only New Zealand required melons be free from fruit fly.

Export and production data

Crop	Total Production Volume (tonnes)	Total Volume Exported (tonnes)	Total Volume Exported (%)	Top Three Export Markets	Market Volume (tonnes)	Market Volume (%)	Fruit Fly Free Required (y/n)
Melons	174,789	12,616	7.22	Hong Kong Singapore New Zealand	4,584 3,350 3,305	36.33 26.55 26.20	n n y

* Data from The Australian Horticultural Statistics Handbook 2000 – 2001 and from AQIS web page.

Export market quarantine information

Hong Kong:
Plants, Import Permits and Phytosanitary Certificates must be declared to the Customs and Excise Service on arrival.

Singapore:
An Import Permit is required for all plant material imported by air and all propagating material. A Phytosanitary Certificate is required for all plant material.

New Zealand:
Phytosanitary Certificate and Additional Declaration required. New Zealand prohibits the import of fruit fly host material from Australia unless it has been suitably treated in accordance with the Arrangement between the New Zealand Ministry of Agriculture and Forestry and the Australian Quarantine and Inspection Service.

For more information see appendix 1.

Current treatment

Methyl bromide fumigation
Area Frredom and Winter window (NZ)
Dimethoate dip (NZ)

Alternative treatments

There is little information published about alternative dinfestation treatments for melons. The treatments registered for use in NZ may prove to be acceptable alternatives for other export markets. Strategies such as Area Freedom and Winter Windows should be researched for other markets.

Dimethoate is also used for surface insects. This treatment is under review and so other fumigants such as pyrethrum may be more sustainable alternative treatments.

Paull and Armstrong (1994) suggest vapour heat treatment as a possible alternative for melons and so this could be investigated further.

Recommendations

More research is required for melons particularly for melons grown in fruit fly areas. Alternative treatments could include;

- Area freedom for selected districts
- Vapour heat treatment for melons grown in fruit fly areas
- Pyrethrum or other fumigants for surface insects to replace dimethoate dipping.

3.14 NASHI FRUIT

Target pests: Light brown apple moth, coddling moth

Nashi Fruit are Australia's eighteenth largest exported fruit crop with 260 tonnes being exported in 1999/2000. None of Australia's top three export markets require nashi fruit to be fruit fly free.

Export and production data

Crop	Total Production Volume (tonnes)	Total Volume Exported (tonnes)	Total Volume Exported (%)	Top Three Export Markets	Market Volume (tonnes)	Market Volume (%)	Fruit Fly Free Required (y/n)
Nashi fruit	5,375	260	4.84	Singapore	244.0	93.85	n
				Hong Kong	8.1	3.12	n
				Malaysia	5.7	2.19	n

* Data from The Australian Horticultural Statistics Handbook 2000 – 2001 and from AQIS web page.

Export market quarantine information

Singapore:
An Import Permit is required for all plant material imported by air and all propagating material. A Phytosanitary Certificate is required for all plant material.

Hong Kong:
Plants, Import Permits and Phytosanitary Certificates must be declared to the Customs and Excise Service on arrival.

Malaysia:
Phytosanitary Certificates for plant products that are hosts of Khapra beetle from infested countries. Even with valid phytosanitary documents, produce will be inspected at checkpoints to ensure that no post-treatment infestation has occurred.

Current treatment

Methyl bromide
Cold treatment

Alternative treatments

Irradiation with gamma radiation has proven to be an effective treatment for apples infested with fruit fly. Apples irradiated with gamma radiation doses of 25, 50, 75 and 100 Gy at 1048 Gy per hour showed no emergence of adult fruit fly (*Anastrepha frateculus*) at any of the doses tested (Arthur, V. *et al.* 1996). It is likely that the same treatment will be able to be used on nashi fruit as well. Radiation provides an alternative to fumigation with methyl bromide however it is not currently registered for use on most food products in Australia.

Cold treatment is already registered for fruit fly control on infested apples in Australia (USDA Treatment Manual T107-d). Apples infested with larvae and eggs of *Ceratitis capitata* and stored at 0.5°C for 14 days or 1.5°C for 16 days showed no survivors and no fruit injury (Sproul, A.N., 1976). Gain, it is likely that this treatment will be an alternative for nashi fruit. These results indicate that the treatment is adequate to meet export requirements to obtain entry to quarantine areas (Sproul, A.N., 1976).

Combination treatments often reduce the amount of time that each treatment requires and this reduces the risk of damage to the fruit. Apples infested with Brownheaded leafroller, *Ctenopseustis obliquana,* and lightbrown apple moth, *Epiphyas postvittana*, exposed to a high-temperature controlled atmosphere of 2% O_2 and 5%CO_2 at 40°C for 8 hours combined with cold storage (0°C for 7 weeks) resulted in complete kill (Whiting, D.C. *et al.*, 1999).

Treatment	**Advantages**	**Disadvantages**
Radiation	Rapid and effective	Expensive, low consumer acceptance.
Cold Storage	Already registered for use on apples, easy to apply and no residues	Long treatment time, risk of chilling injury
High Temperature Controlled Atmosphere + Cold Storage	Reduced treatment time increases shelf life	CA facilities are expensive

Recommendations

There are several alternative treatments for nashi fruit.

- The treatment that is easiest to implement is cold storage + CA as facilities are available and there are no obstacles for consumer acceptability.
- Combination treatments including heat and cold storage may also be useful if the treatment time can be reduced
- Irradiation is also a possibility. Work needs to be done to register the treatment and to determine the tolerance of apple varieties to this treatment.
- Phosphine may be an alternative although some research found host intolerance in apples and this may also be the case for nashi fruit (Paull and Armstrong, 1994).

3.15 NECTARINES

Target pests: Fruit fly, light brown apple moth and surface insects

Nectarines are Australia's eighth largest exported fruit crop with 5,167 tonnes being exported in 1999/2000. Only one of Australia's top three export markets requires nectarines to be fruit fly free.

Export and production data

Crop	Total Production Volume (tonnes)	Total Volume Exported (tonnes)	Total Volume Exported (%)	Top Three Export Markets	Market Volume (tonnes)	Market Volume (%)	Fruit Fly Free Required (y/n)
Nectarines	27,423	5,167	18.84	Taiwan	3,306	63.98	y
				Hong Kong	1,569	30.37	n
				Singapore	126	2.44	n

* Data from The Australian Horticultural Statistics Handbook 2000 – 2001 and from AQIS web page.

Export market quarantine information

Taiwan:
Phytosanitary Certificate and Additional Declaration required. Separate Additional Declarations required for Tasmania and the Mainland States. To prevent the infestation of airfreight consignments of mainland commodities after fruit fly disinfestation and airfreight consignments of commodities from Tasmania, the new requirements that must be complied with from 1 September are (a) that all vented cartons of fruit fly host commodities must have the vents screened with mesh of a diameter less 1.6mm; OR (b) the transfer of fruit from the place of treatment to the airport loading for export must be in a closed vehicle. For more information see appendix 1.

Hong Kong:
Plants, Import Permits and Phytosanitary Certificates must be declared to the Customs and Excise Service on arrival.

Singapore:
An Import Permit is required for all plant material imported by air and all propagating material. A Phytosanitary Certificate is required for all plant material.

Current treatment

Methyl Bromide: 48 g MB/m3 for 2 or 3 hours at 21°C (Harvey, J.M. *et al.*, 1982).
Cold Treatment

Alternative treatments

Cold storage is a currently accepted means of disinfestation for nectarines. The USDA has registered its use for nectarines from Argentina (Treatment Manual T107-c) and South Africa (Treatment Manual T107-e). Treatment T107-c is for the insect *Anastrepha suspensa.* The treatment schedule is 0 to 3°C for 18 to 22 days. Research has also shown that this insect could be successfully controlled in peaches by cold storage for 8.3 days at –0.56°C (Benschoter, C.A., 1988). A similar treatment could be applied to nectarines.

In addition to low temperature a controlled atmosphere treatment could be used in combination. A controlled atmosphere of 0.25% O_2 (balance N_2) at 20°C was tolerated for between 2.8 and 5.2 days depending on cultivar (Ke, D. *et al.*, 1994). The time to reach 100% mortality of some insects suggests that 0.25% O_2 at 20°C is probably not suitable for postharvest disinfestation while 0.21% O_2 at 0°C merits further investigation (Ke, D. *et al.*, 1994).

Heat treatments are another alternative treatment. They have varying degrees of success with stonefruit. Nectarines with seed temperatures raised to 47.2°C for 2 minutes by a forced air heat treatment over 4 hours resulted in firmer fruit which retained the ability to soften, the treatment did not adversely affect the quality and marketability of the fruits (Obenland, D.M., *et al.*, 1999). High temperature forced air is a cheaper alternative to vapour heat treatment and could be a possible alternative treatment.

Hot water immersion at 49.4 -50°C for 5-25 minutes is also another possible alternative. This treatment reduced the numbers of *Anastrepha suspensa* eggs but the treated fruit were unacceptable when immersed for 10 minutes or more due to shriveling, scald and bruising, unusual flavor, aroma and colour (Sharp, J.L., 1990). Treatment at 50°C for 25 minutes was also found to render the fruits unmarketable (Obenland, D.M., *et al.*, 1997). The addition of osmotic buffers did improve the results. For example, sodium chloride at a concentration of 200 mM reduced the mean injury rating from 3.9 (severe) to 1.9 (slight damage), at 46°C the slight amount of injury was eliminated in the presence of NaCl (Obenland, D.M., *et al.*, 1997).

Hot water treatment, for the disinfestation of *Thrips obscuratus,* at 50°C for 2 minutes removed 98% of adults from nectarines and the fruit tolerated the treatment (McLaren, G.F., *et al.*, 1997). This could be investigated further for other insects.

Another possible alternative treatment is irradiation. Medfly eggs in infested nectarines treated at 0.4-0.5 kGy in a Cobalt-60 irradiator did not hatch, there were no differences in sensory qualities between nectarine samples irradiated at 0.3 kGy and their controls, however differences were found in the texture and flavor of nectarines at 1 kGy (Moy, J.H., *et al.*, 1983). Peach infested with *Ceratitis capitata* required a dose of 50 Gy gamma radiation from cobolt-60 to completely inhibit the emergence of adults (Arthur, V., *et al.*, 1993). The species or variety, ripeness and moisture content and presence of bruised areas on the fruits had considerable effects on radiation treatment (Kaneshiro, K.Y., *et al.*, 1983). No insects within treated fruit survived to the adult stage even at radiation doses under 0.6 kGy (Kaneshiro, K.Y., *et al.*, 1983). Gamma radiation might be considered as a possible alternative to quarantine treatment of fruit (Kaneshiro, K.Y., *et al.*, 1983).

Nectarines have been shown to be intolerant to phosphine fumigation (Paull and Armstrong, 1994).

Treatment	Advantages	Disadvantages
Cold treatment	Already registered for use, easy to apply and no residues.	Long treatment times shorten shelf life, risk of chilling injury.
Controlled atmosphere	Reduce the risk of product damage as treatment times reduced.	CA facilities expensive.
High temperature forced air	Cheaper than vapour heat treatment.	Longer treatment time, small margin for error.
Hot water immersion	Low cost and short treatment time.	Products may be damaged by hot water
Irradiation	Rapid and effective.	Expensive, low consumer acceptance

Recommendations

The treatments which show the most promise for nectarines are;

- Cold storage
- Cold storage plus a low oxygen atmosphere
- Irradiation in an effort to reduce the disinfestation treatment time

3.16 ORANGES

Target pests: Fruit fly and surface insects

Oranges are Australia's largest exported fruit crop with 110,934 tonnes being exported in 1999/2000. Of Australia's top three export markets, only the United States of America has specific fruit fly requirements for oranges.

Export and production data

Crop	Total Production Volume (tonnes)	Total Volume Exported (tonnes)	Total Volume Exported (%)	Top Three Export Markets	Market Volume (tonnes)	Market Volume (%)	Fruit Fly Free Required (y/n)
Oranges	446,000	110,934	24.87	USA	26,408	23.81	y
				Malaysia	22,582	20.36	n
				Hong Kong	21,336	19.23	n

* Data from The Australian Horticultural Statistics Handbook 2000 – 2001 and from AQIS web page.

Export market quarantine information

USA:
Import Permit, Phytosanitary Certificate and Additional Declaration required. Ony from: Riverland District of South Australia, Sunraysia district of Victoria and New South Wales and the Riverina district of New South Wales. All farms, packing plants and treatment facilities must be registered in accordance with USDA requirements.

For more information see appendix 1.

Malaysia:
Phytosanitary Certificates for plant products that are hosts of Khapra beetle from infested countries. Even with valid phytosanitary documents, produce will be inspected at checkpoints to ensure that no post-treatment infestation has occurred.

Hong Kong:
Plants, Import Permits and Phytosanitary Certificiates must be declared to the Customs and Excise Service on arrival.

Current treatment

Methyl Bromide

Cold Treatment (Approved USDA and Japan)

Alternative treatments

Cold treatment is a registered quarantine treatment for citrus (Williams, P. *et al*., 1999) and it is currently the main technology acceptable in international trade with work done in Australia resulting in market access for several citrus cultivars (DeLima, C.P.F., 2001). Cold treatment provides an alternative for the disinfestation of citrus against fruit fly to methyl bromide, however most citrus are chilling sensitive (Murata, T., 1990). This problem may be overcome by treatment with a 0.2 to 0.35% emulsion of sucrose fatty acid esters and storage at 1°C for a specified time, which significantly reduces chilling-induced pitting (Murata, T., 1990).

Post harvest cold treatment schedules range from 0°C for 14 days to 2.5°C for 22 days and are considered to achieve 99.6% level of efficiency in all susceptible hosts of Queensland fruit fly (*Dracus tryoni*) (Hocking, D.F., 2001). By combining other treatments the treatment period may be shortened without causing damage to the fruit (DeLima, C.P.F., 2001). The main disadvantage of the cold treatment for citrus is that is does not suit all citrus from all climates in Australia. Losses are suffered from cold damage from fruit harvested from warmer climates (De Lima, 2001). Cold treatment technology may be improved by a pre-treatment such as a short-term heat treatment which can reduce chilling injury (hot water dips for 2 – 3 minutes at 52 – 53°C or hot water brushing for 20 seconds at 53°C (De Lima, 2001). There is also a trade-off between temperature and exposure time, different combinations suit different varieties of citrus (De Lima, 2001).

Controlled atmospheres have not proven to be effective against fruit fly infestation. Oranges infested with eggs or larvae of Queensland fruit fly (*Dacus tryoni*) and held in nitrogen for 1 to 4 days at 20°C showed 94% mortality of larvae but only 22% mortality of eggs, it seems to have no potential as a disinfestation treatment for fresh fruit (Rigney, C.J. *et al*., 1983). Fruit coatings have been shown to siginificantly reduce fruit fly infestation levels within fruits and are a possible future quarantine treatment (Hallman, G.J., 2001).

Heat treatments for fruit fly disinfestation have also been studied for control in citrus fruit (Schirra, M., 1999), methods such as hot water, hot air, electromagnetic energy and combination treatments can be used in citrus for the control of insect pests (Jordan, R.A., 2001). Radio frequency heating can be faster than conventional heating with less total heat applied to the surface of the fruit, resulting in less surface damage however it has never been commercially applied due to the higher moisture content of fresh produce (Hallman, G.J., 2001).

Hot air treatments are also available for the disinfestation of oranges. Oranges exposed to moist, forced air at 46, 47 or 50°C for 1-4 hours could not be distinguished from untreated fruits proving that this is a promising non-chemical quarantine treatment for oranges (Shelly, K.C. *et al*., 1994). Hot water dips at a 25°C core temperature for 42 minutes led to reduced fruit acidity, however they reduced the number of viable spores of *Colletotrichum gloesporioides*, *Penicillium digitatum* and *P. italicum* (Williams, M.H. *et* *al.*, 1994). The fruit were firmer than unheated fruit and they also showed enhanced colour development, however collapsed oil glands were observed after cold storage (Williams, M.H. *et al.*, 1994). Heat treatments are effective against a range of insects including fruit fly (Corcoran, R.J., 2001).

Gamma radiation at 0.049-0.047 kGy/min, alone and in combination with cold treatments showed a synergistic effect when both were applied together (Ohta, A.T. *et al.*, 1989). Infested oranges stored for 14-21 days at 5.5°C required a radiation dose of 0.30 kGy or less to result in negligible egg hatch with shortened durations of cold treatment requiring higher radiation dosages to achieve similar mortality rates (Ohta, A.T. *et al.*, 1989). Irradiation treatment of citrus for fruit flies may be feasible since doses will be in the range 75-150 Gy (Corcoran, R.J., 2001).

Dimethoate dipping involves the full immersion of fruit in a dip containing 400mg/L dimethoate for one minute and dimethoate flood spraying entails flood spraying the fruit with a mixture containing 400mg/L at an application rate of 16L/min per square metre of the area being flood sprayed providing complete coverage of the fruit for 10 seconds after which the fruit must remain wet for 60 seconds (Hocking, D.F., 2001). Both of these treatments considered to achieve a 99.6% level of efficiency in hosts of Queensland fruit fly (*Dracus tryoni*) (Hocking, D.F., 2001).

Phosphine is the only fumigant other than methyl bromide that is registered for postharvest disinfestation of durable food in Australia (Williams, P., 2001). Phosphine requires a treatment time of 2 to 3 days at concentrations of 1200ppm (Corcoran, R.J., 2001). Fumigation for 16 hours at 20°C with an initial phosphine concentration of 0.98g/m3 resulted in 96.4% mortality of *Bactrocera tryoni* larvae which does not meet the interstate (99.5%) or export (99.9%) requirements (Williams, P. *et al.*, 1999). A 48 hour exposure at 23 or 25°C with initial phosphine concentrations of 1.67 g/m3, topped up to 0.7 g/m3 after 24 hours, achieved a mortality rate of 9.998% which would meet requirements for interstate trade and possibly also for international (Williams, P. *et al.*, 1999).

Registered cold treatments for Citrus (De Lima, 2001)

Exports to Japan: Oranges 16 days at 1.0 + 0.5°C.
Exports to Korea: oranges and lemons as approved for Japan.
Export to USA: Using the USDA treatment schedule. A variation may be obtained providing the data is acceptable to the USDA.
Other countries: In general all other countries have set treatments based either on the USDA treatment schedule or on the approvals given by Japan.

Ethylene dibromide and methyl bromide are included as treatments into some countries (Pacific Island nations, Caribbean Island nations and Taiwan). However methyl bromide is phytotoxic to citrus.

Treatment	Advantages	Disadvantages
Cold treatment	Already approved for citrus, easy to apply and no residues.	Long treatment times reduce shelf life, risk of chilling injury.
High temperature moist forced air	Cheaper than vapour heat treatment.	Longer treatment time, small margin for error.
Hot water immersion	Low cost, short treatment time.	Potential to damage product.
Irradiation	Rapid and effective.	Expensive and low consumer acceptance.
Controlled atmosphere	Reduced treatment time, which reduces the risk of product damage.	CA facilities expensive.
Heat treatment	Reduces chilling injury. Grapefruit are the most tolerant of this treatment	Costly and makes disinfestation more complex
Dimethoate dips and flood spraying	Effective, cheap and readily available.	Problems with chemical residues, potential health risk for users.
Phosphine	Likely fumigation alternative to methyl bromide, option for point of entry fumigation for live insects.	Long treatment time, not 100% mortality. Highly corrosive.

Recommendations
Possible alternative treatments for oranges would include;

- Cold with a more flexible time/temperature schedule.
  - Further work could be done to investigate raising the treatment temperature in an effort to reduce the risk of chilling injury to the fruit.
  - Heat treatment or coatings as a pre-treatment to reduce chilling injury. The pre-treatments may not have to be registered as a part of the disinfestation protocol as they relate to fruit quality rather than insect mortality.

- Treatment with hot air may be an option for cultivars and districts where chilling injury is a particular problem.

- Irradiation and research is needed to determine the tolerance of oranges to this treatment

- Area freedom for some districts

- Phosphine may be a possible alternative fumigant but the tolerance of oranges to this treatment needs to be determined.

3.17 PAPAYA

Target pests: Fruit fly and surface insects

Export and production data

Papaya is a growing industry in Australia and currently there is no data for export of this fruit.

Crop	Total Production Volume (tonnes)	Total Volume Exported (tonnes)	Total Volume Exported (%)	Top Three Export Markets	Market Volume (tonnes)	Market Volume (%)	Fruit Fly Free Required (y/n)
Papaya	5,394						

* Data from The Australian Horticultural Statistics Handbook 2000 – 2001 and from AQIS web page.

Export market quarantine information

Papaya is a fruit fly host and so if papaya was exported to a market that has restrictions then it would have to be fumigated with methyl bromide.

Current treatment

Methyl bromide

Alternative treatments

A lot of work has been done for papaya grown in Hawaii and exported to the United States. The results of that work could be used as the basis for research in Australia.

The USDA has approved the use of high temperature forced air for papaya from Belize and Hawaii (USDA Treatment Manual, T103-d-2) and irradiation of papaya from Hawaii (USDA Treatment Manual T105-a-1).

Other research has shown that fruit treated with high temperature forced air until the centre reached 41- 47.2°C at 40-60% relative humidity, then hydro cooled to 30°C showed no survival of *Ceratitis capitata* at temperatures between 46.2 – 47.2°C and no survival of *Bactrocera cucurbitae* or *Bactrocera dorsalis* at temperatures between 45.2 – 46.2°C (Armstrong *et al*., 1989). Treatment time was between 1 and 2 hours and the treatment was not detrimental to fruit quality (Armstrong *et al*., 1989). A semi-automated system for disinfestation with hot air has also been studied (Winkelman *et al*., 1990). American treatment using high temperature forced air and vapour heat treatment consist of heating the fruit until the core temperature reaches 47.5°C, both treatments taking around 6 hours (Nishijima, 1995). Vapour heat treatment is conducted at 100% humidity during the last phase of the treatment (Nishijima, 1995). Vapour heat gives better disease control than high temperature forced air and fruit quality is comparable (Nishijima, 1995).

A single hot water dip at 49°C for 15 minutes provides the same level of disease control as the postharvest application of the fungicide thiabendazole applied to either high temperature forced air or vapour heat treated papayas (Nishijima, 1995). A double hot water dip (42°C for 30 min followed by 49°C for 30 min) as a quarantine treatment was used in Hawaii from 1984 to 1992 for the control of disease, however the fruit quality suffered (Nishijima, 1995).

Semipermeable shrinkwrap film can be used as a means of disinfestation. The film Cryovac, D-955 was used on fruit infested with eggs and larvae of *Ceratitis capitata* and *Dacus cucurbitae*, the fruit were wrapped and held for 3 to 6 days (Jang, 1990). Larvae began to leave after 30 to 60 minutes and were trapped between the skin and the film, it was essential that the film was continuous and that the fruit were wrapped properly (Jang, 1990).

Carbonyl sulfide may be a suitable fumigant for surface insects on papaya (Chen and Paull, 1998).

Treatment	**Advantages**	**Disadvantages**
High temperature forced air	Lower cost than vapour heat treatment	Longer treatment times
Vapour heat treatment	Less damaging than hot water	Small margin for product damage
Hot water treatment	Lower cost than vapour heat treatment, short treatment time	Risk of damage to products
Irradiation	Sort treatment time	Expensive, not currently approved and low consumer acceptability
Carbonyl sulfide	Short treatment time	Chemical residues and low consumer acceptability
Cold treatment	Longer treatment time	Some risk of chilling injury

Recommendations

The following treatments are the most promising alternatives for papaya;

- Cold treatment (USDA approved for some countries, Treatment Manual T107-a, 0 to 4°C for 10 to 16 days).

- Vapour heat treatment (USDA approved treatment, Treatment Manual T106-b-4, 44.5°C for 8.75 hours then cool).

- Irradiation (USDA approved treatment, Treatment Manual T105-a-1, 250 Gy).

3.18 PEARS

Target insects: Light brown apple moth, codling moth, fruit fly

Pears are Australia's fourth largest exported fruit crop with 16,009 tonnes being exported in 1999/2000. None of Australia's top three export markets require pears to be fruit fly free.

Export and production data

Crop	Total Production Volume (tonnes)	Total Volume Exported (tonnes)	Total Volume Exported (%)	Top Three Export Markets	Market Volume (tonnes)	Market Volume (%)	Fruit Fly Free Required (y/n)
Pears	156715	16009	10.22	Singapore	6018	37.59	n
				Malaysia	2864	17.89	n
				Hong Kong	2437	15.22	n

* Data from The Australian Horticultural Statistics Handbook 2000 – 2001 and from AQIS web page.

Export market quarantine information

Singapore:
An Import Permit is required for all plant material imported by air and all propagating material. A Phytosanitary Certificate is required for all plant material.

Malaysia:
Phytosanitary Certificates for plant products that are hosts of Khapra beetle from infested countries. Even with valid phytosanitary documents, produce will be inspected at checkpoints to ensure that no post-treatment infestation has occurred.

Hong Kong:
Plants, Import Permits and Phytosanitary Certificates must be declared to the Customs and Excise Service on arrival.

Current treatment

Methyl bromide

Cold treatment

Alternative treatments

Cold treatment is a registered treatment for pears in Australia exported to the USA (USDA Treatment Manual T107-d). The treatment schedule is 0 to 4°C for 12 to 22 days.

Research has shown that apples infested with larvae and eggs of *Ceratitis capitata* and stored at 0.5°C for 14 days or 1.5°C for 16 days showed no survivors and no fruit injury (Sproul, A.N., 1976). This suggests that the treatment is adequate to meet quarantine requirements and it is likely that the treatment will be applicable to pears as well (Sproul, A.N., 1976). The insect *Anastrepha suspensa* could also be successfully controlled in pears by cold storage for 8.3 days at –0.56°C (Benschoter, C.A., 1988).

Combination treatments often reduce the amount of time that each treatment requires and this means a reduced risk of damage to the fruit. Apples infested with Brown headed leaf roller, *Ctenopseustis obliquana,* and light brown apple moth, *Epiphyas postvittana,* exposed to a high-temperature controlled atmosphere of 2% O_2 and 5%CO_2 at 40°C for 8 hours combined with cold storage (0°C for 7 weeks) resulted in complete kill (Whiting, D.C. *et al.,* 1999). These treatments could be investigated to reduce the disinfestation treatment time required.

Another possible alternative treatment is irradiation. Irradiation with gamma radiation has proven to be an effective treatment for both apples and pears infested with fruit fly. Apples irradiated with gamma radiation doses of 25, 50, 75 and 100 Gy at 1048 Gy per hour showed no emergence of adult fruit fly (*Anastrepha frateculus*) at any of the doses tested (Arthur, V. *et al.* 1996). Radiation provides an alternative to fumigation with methyl bromide however it is not currently registered for use on most food products in Australia.

Pears have been reported to be intolerant of phosphine fumigation (Paull and Armstron, 1994).

Treatment	Advantages	Disadvantages
Cold treatment	Already registered for use on pears, easy to apply and no residues	Long treatment time, risk of chilling injury
High temperature controlled atmosphere plus cold storage	Reduced treatment time increases shelf life	CA facilities are available but expensive
Irradiation	Rapid and effective	Expensive, low consumer acceptance.

Recommendations

There are several alternative treatments for pears.

- The treatment that is easiest to implement is cold storage (USDA 107-d, approved for Australian apples and pears)

- Treatment times may be reduced by developing a combination treatment of heat, CA + cold. CA facilities are available and there are no obstacles for consumer acceptability for these non-chemical treatments.

- Irradiation is also a possibility. Work needs to be done to register the treatment and to determine the tolerance of apple varieties to this treatment.

3.19 PERSIMMON

Target insects: Fruit fly and surface insects

Export and production data

The persimmon industry is a growing industry and there are no export data currently available.

Crop	Total Production Volume (tonnes)	Total Volume Exported (tonnes)	Total Volume Exported (%)	Top Three Export Markets	Market Volume (tonnes)	Market Volume (%)	Fruit Fly Free Required (y/n)
Persimmon	575						y

* Data from The Australian Horticultural Statistics Handbook 2000 – 2001 and from AQIS web page.

Export market quarantine information

Persimmons grown in fruit fly areas would be deemed to be a fruit fly host and would have to be fumigated with methyl bromide.

Current treatment

Methyl bromide

Alternative treatments

There is little information available for persimmons although the USDA has approved cold treatment for Italian persimmons (USDA Treatment Manual T107-a).

Recommendations

More research is required for this crop. The most likely alternative treatments include;

- Cold treatment
- Area freedom or a systems approach for some districts
- Irradiation

3.20 PLUMS

Target insects: light brown apple moth, fruit fly and surface insects

Plums are Australia's seventh largest exported fruit crop with 6,330 tonnes being exported in 1999/2000. Of Australia's top three export markets, only Taiwan has specific fruit fly requirements for plums.

Export and production data

Crop	Total Production Volume (tonnes)	Total Volume Exported (tonnes)	Total Volume Exported (%)	Top Three Export Markets	Market Volume (tonnes)	Market Volume (%)	Fruit Fly Free Required (y/n)
Plums	15,306	6,330	41.36	Hong Kong	3,623	57.24	n
				Singapore	878	13.87	n
				Taiwan	718	11.34	y

* Data from The Australian Horticultural Statistics Handbook 2000 – 2001 and from AQIS web page.

Export market quarantine information

Hong Kong:
Plants, Import Permits and Phytosanitary Certificates must be declared to the Customs and Excise Service on arrival.

Singapore:
An Import Permit is required for all plant material imported by air and all propagating material. A Phytosanitary Certificate is required for all plant material.

Taiwan:
Phytosanitary Certificate and Additional Declaration required. Separate Additional Declarations required for Tasmania and the Mainland States. To prevent the infestation of airfreight consignments of mainland commodities after fruit fly disinfestation and airfreight consignments of commodities from Tasmania, the new requirements that must be complied with from 1 September are (a) that all vented cartons of fruit fly host commodities must have the vents screened with mesh of a diameter less 1.6mm; OR (b) the transfer of fruit from the place of treatment to the airport loading for export must be in a closed vehicle. For more information see appendix 1.

Current treatment

Methyl Bromide: 48 g MB/m3 for 2 or 3 hours at 21°C.

Cold Treatment

Alternative treatments

The USDA has approved the use of cold treatment for plums from several countries (Treatment Manual, T107-a). The treatment schedule is 0 to 4°C for 10 to 16 days. Research has shown that this treatment time can be reduced. For example *Anastrepha suspensa* could be successfully controlled in pears and peaches by cold storage for 8.3 days at −0.56°C (Benschoter, C.A., 1988).

Another possible alternative treatment is a hot water treatment of 49.4 -50°C for 5-25 minutes. Hot water treatment for the disinfestation of *Thrips obscuratus* was 50°C for 2 minutes, which was tolerated by the fruit (McLaren, G.F., *et al.*, 1997).

Irradiation has also be tested on plums. However, gamma radiation treatment of plums was influenced by the ripeness and moisture content of the fruit and the presence of bruised areas, no insects within treated fruit survived to the adult stage even at doses under 0.6 kGy (Kaneshiro, K.Y., *et al.*, 1983). Results of plums infested with Mediterranean fruit fly and treated at 0.4-0.5 kGy in a Cobolt-60 irradiator were inconclusive, there were no differences in sensory qualities between plums irradiated at 0.3 kGy and their controls however differences were found in the texture at 1 kGy (Moy, J.H., *et al.*, 1983). Gamma radiation might be considered as a possible alternative to quarantine treatment of fruit (Kaneshiro, K.Y., *et al.*, 1983).

Treatment	Advantages	Disadvantages
Cold treatment	Already registered for use, easy to apply and no residues.	Long treatment times shorten shelf life, risk of chilling injury.
Hot water immersion	Low cost and short treatment time.	Products may be damaged by hot water
Irradiation	Rapid and effective.	Expensive, low consumer acceptance

Recommendations

The most promising alternative treatments for plums include;

- Cold treatment (USDA approved, Treatment Manual T107-a)
- Cold plus CA to reduce treatment time
- Irradiation

3.21 STRAWBERRIES

Target insects: Fruit fly and surface insects

Strawberries are Australia's thirteenth largest exported fruit crop with 1,735 tonnes being exported in 1999/2000. None of Australia's top three export destinations require strawberries to be fruit fly free.

Export and production data

Crop	Total Production Volume (tonnes)	Total Volume Exported (tonnes)	Total Volume Exported (%)	Top Three Export Markets	Market Volume (tonnes)	Market Volume (%)	Fruit Fly Free Required (y/n)
Strawberry	14,204	1,735	12.21	Singapore	605.0	34.87	n
				Hong Kong	336.0	19.37	n
				United Arab Emirates	306.0	17.64	n

* Data from The Australian Horticultural Statistics Handbook 2000 – 2001 and from AQIS web page.

Export market quarantine information

Singapore:
An Import Permit is required for all plant material imported by air and all propagating material. A Phytosanitary Certificate is required for all plant material.

Hong Kong:
Plants, Import Permits and Phytosanitary Certificates must be declared to the Customs and Excise Service on arrival.

United Arab Emirates:
All plant and plant products exported to United Arab Emirates must comply with Halal, whether certified as Halal or not. Imported and exported plants and products are subject to inspection. If they do not conform to plant quarantine regulations and law, the consignment is subject to return or destruction.

Current treatment

Little research has been done on alternative treatments for strawberries. Area freedom for Tasmania is acceptable for the Japanese market. This approach may be able to be expanded to other regions in Australia.

There is also a possibility of a low temperature and low oxygen treatment although the shelf life following treatment will be very short. Research has indicated that storage for up to 10 days in low oxygen atmospheres (0.25%) at 0 or 5°C could be applied without any apparent effect on strawberry flavour (Paull and Armstrong, 1994).

Irradiation may also be a possible treatment as the treatment time is short, although the tolerance of the fruit would have to be determined.

Recommendations

- Systems approach and area freedom as demonstrated for blue berries and strawberries.
- Cold plus CA may be a possible treatment for areas where the systems approach is not possible.
- Irradiation - although the tolerance of the fruit to this treatment needs to be determined.

3.22 VEGETABLES

Target insects: surface insects and fruit fly (tropical fruit vegetables eg. Tomatoes)

Export and production data

Crop	Total Production Volume (tonnes)	Total Volume Exported (tonnes)	Total Volume Exported (%)	Top Three Export Markets	Market Volume (tonnes)	Market Volume (%)	Fruit Fly Free Required (y/n)
Carrots	256,609	56,200	21.90	Malaysia	23,300	41.46	n
				Singapore	11,479	20.43	n
				Hong Kong	7,269	12.93	n
Onions	233,990	26,159	11.18	Germany	7,046	26.94	n
				UK	3,878	14.82	n
				Japan	3,299	12.61	n
Potatoes	1,326,764	21,293	1.60	Singapore	6,019	28.27	n
				Mauritius	4,301	20.20	n
				Korea, repuplic of	3,739	17.56	n
Cauliflowers	73,433	16,763	22.83	Malaysia	10,446	62.32	n
				Singapore	5,545	33.08	n
				Hong Kong	357	2.13	n
Broccoli	39,389	8,429	21.40	Singapore	3,724	44.18	n
				Malaysia	2,144	25.44	n
				Japan	856	10.16	n
Asparagus	8,877	7,893	88.92	Japan	6,151	77.93	n
				Taiwan	1,453	18.41	n
				Hong Kong	157	1.99	n
Chinese Cabbage	16,034	4,886	30.47	Singapore	1,862	38.11	n
				Hong Kong	1,678	34.34	n
				Taiwan	1,113	22.78	n
Tomatoes	394,336	4,874	1.24	New Zealand	2,837	58.21	y
				Singapore	1,391	28.54	n
				Hong Kong	558	11.45	n
Lettuce	131,140	3,170	2.42	Hong Kong	893	28.17	n
				Malaysia	795	25.08	n
				Singapore	554	17.48	n
Celery	43,208	2,117	4.90	Malaysia	945	44.64	n
				Taiwan	364	17.19	n
				Hong Kong	322	15.21	n

* Data from The Australian Horticultural Statistics Handbook 2000 – 2001 and from AQIS web page.

Export market quarantine information

Germany:

Onion: No specific requirements.

Hong Kong:

Asparagus, carrots, cauliflower, celery, Chinese cabbage, lettuce, tomato: Plants, Import Permits and Phytosanitary Certificates must be declared to the Customs and Excise Service on arrival.

Japan:

Onion: Phytosanitary Certificate required. Option: found free from *Radopholus similis* as a result of inspection during the growing season.
Broccoli, asparagus: no specific requirements.

Korea, the Republic of:

Potatoes: Phytosanitary Certificate required. Prohibited from Western Australia and Victoria. Other than Western Australia and Victoria, state of origin (and postcode) must be indicated on the Phytosanitary Certificate in Box 7.

Malaysia:

Broccoli, carrots, cauliflower, celery, lettuce: Phytosanitary Certificates for plant products that are hosts of Khapra beetle from infested countries. Even with valid phytosanitary documents, produce will be inspected at checkpoints to ensure that no post-treatment infestation has occurred.

Mauritius:

Potatoes: Import Permit, Phytosanitary Certificate and Additional Declaration required.

New Zealand:

Tomato: Phytosanitary Certificate and Additional Declaration required. New Zealand prohibits the import of fruit fly host material from Australia unless it has been suitably treated in accordance with the Arrangement between the New Zealand Ministry of Agriculture and Forestry and the Australian Quarantine and Inspection Service.

Singapore:

Broccoli, carrot, cauliflower, Chinese cabbage, lettuce, potato, tomato: An Import Permit is required for all plant material imported by air and all propagating material. A Phytosanitary Certificate is required for all plant material.

Taiwan:

Asparagus: no specific requirements.
Celery: Phytosanitary Certificate and Additional Declaration required. Only the underground portion of *Apium graveolens* is considered host tissue for white fringed beetle. All vegetables must be free from soil.
Chinese cabbage: Phytosanitary Certificate and Additional Declaration required.

United Kingdom:

Onion: no specific requirements.

Current treatment

For the control of surface pests (thrips, mites, scales, etc) the USDA recommends methyl bromide at the following classifications:

4.5°C: asparagus, cabbage, celery, chicory, cucumber, endive, fresh herbs, leafy vegetables, pepper, snow peas, squash, sweet potato.

10°C: bean, beet, carrot, sweet corn, eggplant, garlic, ginger, green pod vegetables, horse radish, Jerusalem artichoke, okra, onion, parsnip, pea, potato, radish, rutabaga, sugar beet, tomato, turnip.

15.5°C: pumpkin, zucchini.

Alternative treatments

		USDA Treatment Manual	
Bell pepper	vapour heat	T 106-6-1	(44.5°C, 8.75 hours)
Eggplant	vapour heat	T 106-6-2	(44.5°C, 8.75 hours)
Squash	vapour heat	T 106-6-6	(44.5°C, 8.75 hours)
Tomato	vapour heat	T 106-6-7	(44.5°C, 8.75 hours)
Zucchini	vapour heat	T 106-6-8	(44.5°C, 8.75 hours)

Fumigation with methyl bromide has been approved in the United States as a quarantine treatment for vegetable crops, however severe phytotoxic responses shown by some commodities are a major disadvantage to its use (Paull, R.E., *et al.*, 1994).

Phosphine is an alternative fumigant to methyl bromide that has proven to be effective on several fruit products. Fumigation with phosphine is a slower process than for methyl bromide which limits its use commercially despite being shown to be an effective fumigant for fruit flies (Paull, R.E., *et al.*, 1994). Phytotoxity was not a problem when lettuce was treated with phosphine at 0.28, 0.56 or 0.83 g l^{-1} at 4.4 or 24°C, except when the air was circulated at 24°C (Paull, R.E., *et al.*, 1994). Both tomato and bell pepper were uninjured after phosphine fumigation at 5500 to 20000 ppm for 4 days at 14°C (Paull, R.E., *et al.*, 1994). Phosphine has been considered as a quarantine treatment for sweet potato weevil, however the most likely use of phosphine may be as a treatment applied during transport of vegetables in containers constructed for controlled atmosphere applications (Paull, R.E., *et al.*, 1994).

Hydrogen cyanide is another alternative fumigant to methyl bromide. Hydrogen cyanide is not particularly well suited for use as a fumigant due to its solubility in water and relatively high boiling point (26°C) (Paull, R.E., *et al.*, 1994).

Insecticides such as dimethoate and fenthion also provide alternatives to fumigation with methyl bromide. Both of these have been tested in Australia as postharvest dips or sprays for the control of Queensland fruit fly in tomato and cucumber fly in zucchini and rockmelon (Paull, R.E., *et al.*, 1994). A concentration of 400 mg l^{-1} of either of the chemicals gave essentially 100% mortality of eggs and larvae of both insects, with no adverse effects on taste and residue levels were less than 2 mg kg^{-1} (Paull, R.E., *et al.*, 1994). Dipping has advantages over fumigation including the greater likelihood that packinghouse treatments will be carried out immediately after harvest; delays before fumigation usually require commodities to be re-warmed which can reduce storage life (Paull, R.E., *et al.*, 1994). The sustainability of insecticide treatments is questionable.

Vapour heat treatments for disinfestation were developed for fruits 60 years ago but were overshadowed by fumigant treatments, however, now that chemical treatments are being restricted there is a new interest in vapour heat and heat treatments in general (Paull, R.E., *et al.*, 1994). Standard vapour heat treatments consist of a gradual warming to the treatment temperature for the necessary time to kill the insect pest, then rapid cooling back to ambient temperature (Paull, R.E., *et al.*, 1994). Vapour heat treatments for vegetables have been developed for bitter momordica, eggplant, pepper, squash and tomato, with treatments directed at fruit fly the treatment temperatures are in the range of 43-45°C (Paull, R.E., *et al.*, 1994). Commodity injury in affected by heating rate, treatment temperature and exposure time (Paull, R.E., *et al.*, 1994).

High temperature forced air treatments have been developed for papaya and mango infested with fruit fly, the approach is less efficient than vapour heat in warming commodities. However it may be more easily adapted to commercial conditions and existing equipment (Paull, R.E., *et al.*, 1994).

When compared to vapour heat and high temperature forced air, hot water is the most efficient heat treatment (Paull, R.E., *et al.*, 1994). Hot water treatments for fruits and vegetables indicate that most commodities are able to tolerate exposure to 45-55°C water for 10-20 minutes, while peppers were only able to tolerate 51°C for 2.5 minutes (Paull, R.E., *et al.*, 1994). Cucumbers immersed in hot water at temperatures, and for times, sufficient to kill fruit flies, are severely damaged. Cucumbers also experienced enhanced yellowing following hot water treatment at 45 and 46°C for 30 minutes (Paull, R.E., *et al.*, 1994).

Cold treatments for quarantine are available for the treatment of fruits infested with fruit flies and false codling moth, schedules range from 10 days to as long as 22 days at temperatures ranging from less than 0°C to 2°C (Paull, R.E., *et al.*, 1994). Unfortunately, most of the vegetable of quarantine significance are chilling sensitive and would be expected to be damaged by such treatments, the length of exposure to cold makes these treatments impractical for even temperate crops except for export situations that involve extended transit periods (Paull, R.E., *et al.*, 1994). Produce may be conditioned to reduce chilling injury, a large number of chilling-sensitive vegetables have been reported to respond favourably to this conditioning, including cucumber, eggplant, pepper, tomato and watermelon (Paull, R.E., *et al.*, 1994). With conditioning, cold treatment may be a viable option for the quarantine treatment for some vegetables (Paull, R.E., *et al.*, 1994).

Controlled atmospheres have been used for the disinfestation of fruits. However there is little information on the tolerance of vegetables to this treatment (Paull, R.E., *et al.*, 1994). Sweet potato is able to tolerate 2 or 4% O_2 plus 40% CO_2, or 4% O_2 plus 40 or 60% CO_2 for 1 week at 25°C without injury (Paull, R.E., *et al.*, 1994). Lettuce exposed to the equivalent of 0.26 or 0.40% O_2 for 24-52 hours at 2°C in a low pressure system resulted in 100% mortality of green peach aphid with no detrimental effects to the lettuce, similar responses are likely with other vegetables (Paull, R.E., *et al.*, 1994). Modified atmosphere packaging may have potential for insect disinfestation of vegetables, the levels of O_2 and CO_2 that could be used would be similar to those recommended for long-term controlled atmosphere storage (Paull, R.E., *et al.*, 1994). With a large number of films available, with wide ranges of O_2 and CO_2 permeabilities, it should be possible to obtain insecticidal atmospheres applicable to most vegetables (Paull, R.E., *et al.*, 1994). The effectiveness of controlled atmospheres in causing insect mortality is generally increased as relative humidity is lowered, however the potential effects of low relative humidity on insects infesting fresh products are probably limited to the emerged stages, vegetables also tend to be relatively sensitive to water loss compared to fruits so there is little reason to consider low relative humidity as a component of vegetable disinfestation (Paull, R.E., *et al.*, 1994).

Irradiation is a promising, chemical free alternative to methyl bromide for the disinfestation of fresh produce. Fresh fruits and vegetables may be treated with up to 100 krad of ionizing radiation in the USA, however much lower doses are effective in sterilizing many insects (Paull, R.E., *et al.*, 1994). Irradiation in the range 15-50 krad will kill fruit fly, some vegetables may be injured at these levels but most vegetables may be able to tolerate at leased 100 krad, which would result in complete mortality of insects (Paull, R.E., *et al.*, 1994). Tomatoes tolerated 25-100 krad with no impairment of quality, while cucumbers tolerated up to 50 krad without damage (Paull, R.E., *et al.*, 1994). The need for specialized facilities to conduce ionizing radiation treatments makes the likelihood of widespread adoption as a commercial commodity treatment unlikely (Paull, R.E., *et al.*, 1994).

Many of these treatments may also be combined to increase effectiveness, or reduce treatment time. Fumigation plus heat or cold has been found to reduce the amount of fumigant required (Paull, R.E., *et al.*, 1994). Fumigation in combination with modified atmospheres may greatly increase the effectiveness of fumigants, allowing shorter treatment times and lower concentrations of fumigant (Paull, R.E., *et al.*, 1994). Heat and cold may also be used in combination; this approach would require little modification of normal handling procedures for vegetables (Paull, R.E., *et al.*, 1994). Heat, cold and modified atmospheres may all be combined for disinfestation of vegetables (Paull, R.E., *et al.*, 1994).

Treatment	Advantages	Disadvantages
Phosphine and other fumigants	Possible point of entry fumigant for live insects.	Longer treatment times, not 100% mortality.
Insecticidal dips	Effective and readily available, cheap and easy to apply.	Problems with chemical residues, potential health risk for users.
Vapour heat treatment	Less damaging than hot water, widely accepted.	Small margin for error, high cost.
High temperature forced air	Cheaper than vapour heat treatment, no condensation.	Longer treatment times, small margin for error, not suitable for all crops.
Hot water treatment	Lower cost than vapour heat treatment, short treatment time.	Risk of damage to products, difficult to adopt commercially.
Cold treatment	Easy to apply, no residues.	Long treatment times, risk of damage to chilling sensitive vegetables.
Controlled atmospheres	Controlled atmosphere facilities are expensive.	Long treatment times at low temperatures.
Irradiation	Rapid and effective	Low consumer acceptance, expensive.
Combination treatments	Reduces the time required for treatment and so optimizes shelf life, reduces risk of product damage	Difficult to apply commercially

Recommendations

Vegetables are a varied class of products. For products that are fruit fly hosts it is likely that

- vapour heat treatments are the most likely alternative to methyl bromide.

For products that are not fruit fly hosts then the following treatments are possible;

- Cold storage or Combination treatments with cold, heat and CA
- Fumigation with pyrethrum, phosphine or other fumigants
- Area freedom may also be appropriate for some district/pest combinations
- Irradiation

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Appendix 1.

Specific import requirements for some horticultural crops

Tomatoes:

Importing Country - New Zealand

Phytosanitary Certificate and Additional Declaration required. New Zealand prohibits the import of fruit fly host material from Australia unless it has been suitably treated in accordance with the Arrangement between the New Zealand Ministry of Agriculture and Forestry and the Australian Quarantine and Inspection Service concerning the access of host material of fruit fly species of economic significance into New Zealand from Australia.

Additional declarations:

Option 1:

1. The tomatoes in this consignment have been inspected in accordance with appropriate official procedures and found to be free from any visually detectable quarantine pests, specified by the New Zealand Ministry of Agriculture and Forestry,
2. The tomatoes in this consignment have undergone appropriate pest control activities that are effective against those risk group 2 regulated pests specified by NZ MAF,
3. The tomatoes in this consignment have been treated in accordance with Appendix 4 and Appendix 10 of the Arrangement between the New Zealand Ministry of Agriculture and Forestry and the Australian Quarantine and Inspection Service concerning the access of host material of fruit fly species of economic significance into New Zealand from Australia.

OR Option 2:

1. The tomatoes in this consignment have been inspected in accordance with appropriate official procedures and found to be free from any visually detectable quarantine pests, specified by the New Zealand Ministry of Agriculture and Forestry,
2. The tomatoes in this consignment have been sourced from an area free from those risk group 2 regulated pests specified by NZ MAF,
3. The tomatoes in this consignment have been treated in accordance with Appendix 2 of the Arrangement between the New Zealand Ministry of Agriculture and Forestry and the Australian Quarantine and Inspection Service concerning the access of host material of Tephritidae species of economic significance into New Zealand from Australia.

OR option 3:

1. The tomatoes in this consignment have been inspected in accordance with appropriate official procedures and found to be free from any visually detectable

quarantine pests, specified by the New Zealand Ministry of Agriculture and Forestry,
2. The tomatoes in this consignment have been sourced from an area free from those risk group 2 regulated pests specified by NZ MAF,
3. The tomatoes in this consignment have been treated in accordance with Appendix 4 and Appendix 10 of the Arrangement between the New Zealand Ministry of Agriculture and Forestry and the Australian Quarantine and Inspection Service concerning the access of host material of fruit fly species of economic significance into New Zealand from Australia.

OR option 4:

1. The tomatoes in this consignment have been inspected in accordance with appropriate official procedures and found to be free from any visually detectable quarantine pests, specified by the New Zealand Ministry of Agriculture and Forestry,
2. The tomatoes in this consignment have undergone appropriate pest control activities that are effective against those risk group 2 regulated pests specified by NZ MAF,
3. The tomatoes in this consignment have been treated in accordance with Appendix 2 of the Arrangement between the New Zealand Ministry of Agriculture and Forestry and the Australian Quarantine and Inspection Service concerning the access of host material of Tephritidae species of economic significance into New Zealand from Australia.

Oranges:
Importing Country - USA:

Import Permit, Phytosanitary Certificate and Additional Declaration required. Ony from: Riverland District of South Australia, Sunraysia district of Victoria and New South Wales and the Riverina district of New South Wales. All farms, packing plants and treatment facilities must be registered in accordance with USDA requirements.

Additional Declarations:
Option 1:

The citrus fruit was produced in the Riverina District of New South Wales in accordance with the conditions governing the entry of citrus from Australia,
1. Fruit was grown and packed in an area free of economically important fruit flies,
2. The fruit in this shipment was subject to appropriate phytosanitary measures to ensure that the shipment is free of light brown apple moth.

OR option 2:

1. The citrus fruit was produced in the Riverina District of New South Wales in accordance with the conditions governing the entry of citrus from Australia,

2. Subject to in-transit cold treatment,
3. The fruit in this shipment was subject to appropriate phytosanitary measures to ensure that the shipment is free of light brown apple moth.

OR option 3:

1. The citrus fruit was produced in the Sunraysia District of New South Wales in accordance with the conditions governing the entry of citrus from Australia,
2. Fruit was grown and packed in an area free of economically important fruit flies,
3. The fruit in this shipment was subject to appropriate phytosanitary measures to ensure that the shipment is free of light brown apple moth.

OR option 4:

1. The citrus fruit was produced in the Sunraysia District of New South Wales in accordance with the conditions governing the entry of citrus from Australia,
2. Subject to in-transit cold treatment,
3. The fruit in this shipment was subject to appropriate phytosanitary measures to ensure that the shipment is free of light brown apple moth.

OR option 5:

1. The citrus fruit was produced in the Riverland District of South Australia in accordance with the conditions governing the entry of citrus from Australia,
2. Subject to in-transit cold treatment,
3. The fruit in this shipment was subject to appropriate phytosanitary measures to ensure that the shipment is free of light brown apple moth.

OR option 6:

1. The citrus fruit was produced in the Riverland District of South Australia in accordance with the conditions governing the entry of citrus from Australia,
2. Fruit was grown and packed in an area free of economically important fruit flies,
3. The fruit in this shipment was subject to appropriate phytosanitary measures to ensure that the shipment is free of light brown apple moth.

OR option 7:

1. The citrus fruit was produced in the Sunraysia District of Victoria in accordance with the conditions governing the entry of citrus from Australia,
2. Fruit was grown and packed in an area free of economically important fruit flies,
3. The fruit in this shipment was subject to appropriate phytosanitary measures to ensure that the shipment is free of light brown apple moth.

OR option 8:

1. The citrus fruit was produced in the Sunraysia District of Victoria in accordance with the conditions governing the entry of citrus from Australia,
2. Subject to in-transit cold treatment,
3. The fruit in this shipment was subject to appropriate phytosanitary measures to ensure that the shipment is free of light brown apple moth.

Mandarins:
Importing Country - Indonesia:

Phytosanitary Certificate and Additional Declaration required. For the purpose of certifying citrus to Indonesia, mealy bugs are to be classified as injurious pests and a 21 infested unit inspection tolerance on mealy bugs is now permitted for export of citrus to Indonesia. Indonesia prohibits the import of fruit fly host material from Australia unless it has been sourced from an area that Indonesia considers free from fruit fly or has been suitably treated. One of the treatment schedules below must be used for produce originating from areas not designated as free from fruit flies. Treatment is to be included on the Phytosanitary Certificate.

Additional Declarations:

Option 1:
Fumigated with methyl bromide.

OR option 2:
Grown and packed in an area free from Ceratitis capitata and Bactrocera tryoni.

OR option 3:
The produce has been subjected to cold treatment prior to shipping.

OR option 4:
Subject to in-transit cold sterilisation.

Treatment:
For produce from areas not free of one of the fruit flies, the treatment rates for the applicable species may be chosen from the tables below as appropriate:

For Ceratitis capitata (Mediterranean fruit fly):
10 days at 0°C or below
11 days at 0.55°C or below
12 days at 1.11°C or below
14 days at 1.66°C or below
16 days at 2.22°C or below
For Bactrocera tryoni (Queensland fruit fly):
13 days at 0°C or below

14 days at 0.55°C or below
18 days at 1.11°C or below
20 days at 1.66°C or below
22 days at 2.22°C or below

1. In the unlikely event of produce originating from places where both species are present the cold sterilisation treatment for Bactrocera tryoni will be used.
2. Cold sterilisation in transit is permitted, commenced on land, the certificate should have an Additional Declaration specifying the length of time and temperature of treatment prior to shipping and the inspector should be assured there is no break in the temperature recording between shore and ship.
3. Methyl Bromide fumigation at 48 g/m^3 at 21°C, for 2 hrs.

Mandarins:

Importing Country - USA:
See Oranges, USA

Melons:

Importing Country - New Zealand

Phytosanitary Certificate and Additional Declaration required. New Zealand prohibits the import of fruit fly host material from Australia unless it has been suitably treated in accordance with the Arrangement between the New Zealand Ministry of Agriculture and Forestry and the Australian Quarantine and Inspection Service.

Additional Declaration:

Option 1:

1. The watermelons in this consignment have been inspected in accordance with appropriate official procedures and found to be free from any visually detectable quarantine pests, specified by the New Zealand Ministry of Agriculture and Forestry,
2. The watermelons in this consignment have undergone appropriate pest control activities that are effective against those risk group 2 regulated pests specified by NZ MAF,
3. The watermelons in this consignment have been treated in accordance with Appendix 3 and Appendix 4 of the Arrangement between the New Zealand Ministry of Agriculture and Forestry and the Australian Quarantine and Inspection Service concerning the access of host material of Tephritidae species of economic significance into New Zealand from Australia.

OR option 2:

1. The watermelons in this consignment have been inspected in accordance with appropriate official procedures and found to be free from any visually detectable

quarantine pests, specified by the New Zealand Ministry of Agriculture and Forestry,

2. The watermelons in this consignment have undergone appropriate pest control activities that are effective against those risk group 2 regulated pests specified by NZ MAF,
3. The watermelons in this consignment have been treated in accordance with Appendix 10 and Appendix 11 of the Arrangement between the New Zealand Ministry of Agriculture and Forestry and the Australian Quarantine and Inspection Service concerning the access of host material of Tephritidae species of economic significance into New Zealand from Australia.

OR option 3:

1. The watermelons in this consignment have been inspected in accordance with appropriate official procedures and found to be free from any visually detectable quarantine pests, specified by the New Zealand Ministry of Agriculture and Forestry,
2. The watermelons in this consignment have undergone appropriate pest control activities that are effective against those risk group 2 regulated pests specified by NZ MAF,
3. The watermelons in this consignment have been treated in accordance with Appendix 2 of the Arrangement between the New Zealand Ministry of Agriculture and Forestry and the Australian Quarantine and Inspection Service concerning the access of host material of Tephritidae species of economic significance into New Zealand from Australia.

Plum:
Importing Country - Taiwan:

Phytosanitary Certificate and Additional Declaration required. Separate Additional Declarations required for Tasmania and the Mainland States. To prevent the infestation of airfreight consignments of mainland commodities after fruit fly disinfestation and airfreight consignments of commodities from Tasmania, the new requirements that must be complied with from 1 September are (a) that all vented cartons of fruit fly host commodities must have the vents screened with mesh of a diameter less 1.6mm; OR (b) the transfer of fruit from the place of treatment to the airport loading for export must be in a closed vehicle.

Additional declarations:

Option 1:

1. The product has been thoroughly inspected and found free of Ceratitis capitata, Cydia pomonella and Bactrocera tryoni before treatment was started,
2. Subject to in-transit cold sterilisation,

3. The product has been thoroughly inspected and found free from Frankliniella occidentalis (Pergande), 4) The fruit in this consignment has been secured against infestation by fruit flies during transport.

OR option 2:

1. The product has been thoroughly inspected and found free from Frankliniella occidentalis,
2. Fruit has been inspected and found free of Ceratitis capitata, Cydia pomonella and Bactrocera tryoni before treatment was started,
3. Subject to in-transit cold sterilisation.

OR option 3:

1. The product has been thoroughly inspected and found free from Frankliniella occidentalis,
2. Fruit has been inspected and found free of Ceratitis capitata, Cydia pomonella and Bactrocera tryoni before treatment was started,
3. The fruit has been treated prior to shipment,
4. The fruit in this consignment has been secured against infestation by fruit flies during transport.

OR option 4:

1. The product has been thoroughly inspected and found free of Ceratitis capitata, Cydia pomonella and Bactrocera tryoni before treatment was started,
2. The fruit has been treated prior to shipment,
3. The product has been thoroughly inspected and found free from Frankliniella occidentalis (Pergande).

OR option 5:

1. Fruit has been inspected and found free of Ceratitis capitata, Cydia pomonella and Bactrocera tryoni,
2. The product has been thoroughly inspected and found free from Frankliniella occidentalis,
3. The fruit in this consignment has been secured against infestation by fruit flies during transport.

OR option 6:

1. Fruit has been inspected and found free of Ceratitis capitata, Cydia pomonella and Bactrocera tryoni,
2. The product has been thoroughly inspected and found free from Frankliniella occidentalis.

Treatment:

All fruits and vegetables exported to Taiwan must be subjected to either cold treatment or fumigation plus cold treatment prior to export in accordance with ONE of the following schedules:

* Methyl Bromide 32g/m3 at 21°C (69.8°F) or above, chamber load not to exceed 80% of volume.

a. 0 hours fumigation followed by 0.00°C (32F) for 12 days - Sea freight only
b. 0 hours fumigation followed by 1.67°C (35F) for 14 days - Sea freight only
c. 0 hours fumigation followed by 3.33°C (38F) for 18 days - Sea freight only
d. 2 hours fumigation followed by 0.0 - 2.8°C (33 - 37F) for 4 days - Sea and air freight
e. 2 hours fumigation followed by 3.3 - 8.3°C (38 - 47F) for 11 days - Sea and air freight
f. 2½ hours fumigation followed by 3.3 - 4.4°C (38 - 40F) for 4 days - Sea and air freight
g. 2½ hours fumigation followed by 5.0 - 8.3°C (41 - 47F) for 6 days - Sea and air freight
h. 2½ hours fumigation followed by 8.9 - 13.3°C (43 - 47F) for 10 days - Sea and air freight
i. 3 hours fumigation followed by 6.1 - 8.1°C (43 - 47F) for 3 days - Sea and air freight
j. 3 hours fumigation followed by 8.9 - 13.3°C (48 - 56F) for 6 days - Sea and air freight

Nectarines:

Importing Country - Taiwan:

See plums, Taiwan.

Lemons/Limes:

Importing Country - Japan:

Phytosanitary Certificate and Additional Declaration required.

Additional Declarations:

Option 1:

The citrus fruits covered by this certificate are apparently free from Mediterranean fruit fly and Queensland fruit fly.

Mangoes:

Importing Country - Japan:

Phytosanitary Certificate and Additional Declaration required. ONLY Kent, Keitt, Palmer, R2E2 and Kensington variety of mango are approved for export to Japan. Other varieties of mangoes are not permitted to be exported to Japan as data has not been provided by industry to support establishment of a treatment. Country of origin labelling is now required for all goods, including fresh fruits and vegetables.

Additional Declaration:

Option 1:

The fruit has been inspected in accordance with the procedures required in the arrangement between Australia and Japan for the access of mangoes and were found to be free of Mediterranean and Queensland fruit flies.

Avocadoes:
Importing Country - New Zealand

Phytosanitary Certificate and Additional Declaration required. New Zealand prohibits the import of fruit fly host material from Australia unless it has been suitably treated in accordance with the Arrangement between the New Zealand Ministry of Agriculture and Forestry and the Australian Quarantine and Inspection Service concerning the access of host material of fruit fly species of economic significance into New Zealand from Australia.

Additional Declaration:
Option 1:
1. The avocadoes in this consignment have been inspected in accordance with appropriate official procedures and found to be free from any visually detectable quarantine pests, specified by the New Zealand Ministry of Agriculture and Forestry,
2. The avocadoes in this consignment have gone through appropriate pest control activities that are effective against Pseudocercospora purpurea and have been sourced from an approved orchard which has been inspected and found free from symptoms of Avocado sunblotch viroid,
3. The avocadoes in this consignment have been treated in accordance with Appendix 2 of the Arrangement between the New Zealand Ministry of Agriculture and Forestry and the Australian Quarantine and Inspection Service concerning the access of host material of Tephritidae species of economic significance into New Zealand from Australia.

OR option 2:

1. The avocadoes in this consignment have been inspected in accordance with appropriate official procedures and found to be free from any visually detectable quarantine pests, specified by the New Zealand Ministry of Agriculture and Forestry,
2. The avocadoes in this consignment have gone through appropriate pest control activities that are effective against Pseudocercospora purpurea and have been sourced from an approved orchard which has been inspected and found free from symptoms of Avocado sunblotch viroid,
3. The avocadoes in this consignment have been treated in accordance with Appendix 5 of the Arrangement between the New Zealand Ministry of Agriculture and Forestry and the Australian Quarantine and Inspection Service concerning the access of host material of Tephritidae species of economic significance into New Zealand from Australia.

OR option 3:

1. The avocadoes in this consignment have been inspected in accordance with appropriate official procedures and found to be free from any visually detectable quarantine pests, specified by the New Zealand Ministry of Agriculture and Forestry,

2. The avocadoes in this consignment have been sourced from an area free (as verified by official detection survey) from Pseudocercospora purpurea and have been sourced from an approved orchard which has been inspected and found free from symptoms of Avocado sunblotch viroid,
3. The avocadoes in this consignment have been treated in accordance with Appendix 2 of the Arrangement between the New Zealand Ministry of Agriculture and Forestry and the Australian Quarantine and Inspection Service concerning the access of host material of Tephritidae species of economic significance into New Zealand from Australia.

OR option 4:

1. The avocadoes in this consignment have been inspected in accordance with appropriate official procedures and found to be free from any visually detectable quarantine pests, specified by the New Zealand Ministry of Agriculture and Forestry,
2. The avocadoes in this consignment have been sourced from an area free (as verified by official detection survey) from Pseudocercospora purpurea and have been sourced from an approved orchard which has been inspected and found free from symptoms of Avocado sunblotch viroid,
3. The avocadoes in this consignment have been treated in accordance with Appendix 5 of the Arrangement between the New Zealand Ministry of Agriculture and Forestry and the Australian Quarantine and Inspection Service concerning the access of host material of Tephritidae species of economic significance into New Zealand from Australia.

Cherry:
Importing Country - Taiwan:
See nectarine Taiwan.

Berry fruits:
Importing Country - Japan:

Phytosanitary Certificate and Additional Declaration required.

1. Permitted export from Tasmania only. Prohibited export from all other States in Australia.
2. All fresh fruit and vegetable fruit-fly hosts are currently prohibited from mainland Australia.

Additional declaration:

The produce has been produced and packed in Tasmania.

Appendix 2.

USDA Treatment Schedules for Alternative Treatments to Methyl Bromide

T102— Water Treatment

T102-b **Cherimoya from Chile**

Pest: *Brevipalpus chilensis* (Chilean false spider mite of grapes)

Treatment: **T102-b** Soapy water and wax

1. Immerse fruit for 20 seconds in soapy water bath of one part soap solution (such as Deterfruit) to 3,000 parts water.
2. Follow the soapy bath with a pressure shower rinse to remove all the soapy excess.
3. Immerse fruit for 20 seconds in an undiluted wax coating (such as Johnson's Wax Primafresh 31 Kosher fruit coating). The wax coating should cover the entire surface of the fruit.

Important: At the port of entry, the PPQ officer should check to make sure the wax coating covers the entire surface of the fruit.

T102-c **Durian and other large fruits such as breadfruit**

Pest: External Feeders

Treatment: **T102-c** Warm, soapy water and brushing

1. Add detergent (such as Deterfruit) to warm water (110 ° to 120 ° F) at the rate of one part detergent or soap to 3,000 parts water.
2. Immerse the fruit for at least 1 minute in the warm detergent water.
3. Using a brush with stiff bristles, have the importer or the importer's agent scrub each fruit to remove any insects.
4. Using a pressure shower, have the importer or the importer's agent rinse the fruit free from residue (detergent and dead insects).
5. Inspect each brushed and cleaned fruit. Pay particular attention to external feeders such as mealybugs and scales. If any insects remain, have the fruit retreated or have it destroyed.

T102-e **Limes**

Pest: Mealybugs (Pseudococcidae) and other surface pests

Treatment: **T102-e** Hot water immersion

1. Fruit must be treated under supervision of an inspector, in a certified hot water immersion treatment tank.

A. Fruit must be submerged at least 4 inches below the water's surface.

B. Water must circulate continually and be kept at 120.2 °F (or above) for 20 minutes. Treatment time begins when the water temperature reaches at least 120.2 °F in all locations of the tank.

2. Cooling and waxing the fruit are both optional, and are the sole responsibility of the processor.

NOTICE

Phytotoxic damage (increased yellowing) may occur if the temperature reaches 125.6 °F or if the treatment duration significantly exceeds 20 minutes.

T102-b

Limes from Chile

Pest: *Brevipalpus chilensis* (Chilean false spider mite of grapes)

Treatment: **T102-b-1** Soapy water and wax

1. Immerse fruit for 20 seconds in soapy water bath of one part soap solution (such as Deterfruit) to 3,000 parts water.
2. Follow the soapy bath with a pressure shower rinse to remove all the soapy excess.
3. Immerse fruit for 20 seconds in an undiluted wax coating (such as Johnson's Wax Primafresh 31 Kosher fruit coating). The wax coating should cover the entire surface of the fruit.

Important

At the port of entry, the PPQ officer should check to make sure the wax coating covers the entire surface of the fruit.

T102-d

Lychee (litchi) fruit from Hawaii

Pest: ***Ceratitis capitata*** (Mediterranean fruit fly) and ***Bactrocera dorsalis*** (Oriental fruit fly)

Treatment: T102-d Hot water immersion

1. Lychees must be thoroughly examined at the packinghouse by an inspector and found free of ***Cryptophlebia spp.*** (Lychee fruit moth) and other plant pests[1]
2. Fruit must be grown and treated in Hawaii, under monitoring of an inspector, in a certified hot water immersion treatment tank.[2]

1 Because ***Eriophyes litchii*** (lychee mite) cannot be effectively detected by inspection, and would not be effectively eliminated by hot water immersion, the lychees may not be shipped into Florida. Each carton must be stamped "Not for importation into or distribution in Florida."

A. Fruit must be submerged at least 4 inches below the water's surface.

B. Water must circulate constantly, and be kept at 120.2 °F (or above) for 20 minutes. Treatment time begins when the water temperature reaches at least 120.2 °F in all locations throughout the tank.[3]

Temperatures exceeding 121.1 °F can cause phytotoxic damage.

3. Hydrocooling for 20 minutes at 75.2 °F is recommended, though not required, to prevent injury to the fruit from the hot water treatment.

T102-a

Mango

Pest: ***Ceratitis capitata*** (Mediterranean fruit fly), *Anastrepha spp., Anestrepha ludens* (Mexican fruit fly)

Treatment: **T102-a** Hot water dip

Fruit must be treated in country of origin at a certified facility and under the monitoring of APHIS personnel.

1. Pulp temperature must be 70 °F or above before start of treatment.
2. Fruit must be submerged at least 4 inches below water surface.
3. Water must circulate constantly and be kept at 115 °F throughout the treatment with the following tolerances:

- ***During the first five minutes of a treatment***—temperatures below 113.7 °F are allowed during the first five minutes of a treatment only if the temperature is at least 115 °F at the end of the five minute period.
- ***For treatments lasting 65 to 75 minutes***—temperatures may fall as low as 113.7 °F for no more than 10 minutes under emergency conditions.
- ***For treatments lasting 90 minutes***—temperatures may fall as low as 113.7 °F for no more than 15 minutes under emergency conditions.

4. Determine the dip time from Tables **Table 5-2-1**, **Table 5-2-2**, or **Table 5-2-3**.

2 Use of Treatment T102D is at the risk of the shipper. Limited research on fruit quality after treatment application indicated that fruit quality varies among cultivars. 'Kaimana' and 'Kwai Mi' ('Tai So') tolerate the treatment better than 'Brewster' and 'Groff'; no other cultivars were tested.

3 Treatment does not begin until after the fruit is immersed and the water temperature recovers to 120.2 °F (or above). Therefore, before the start of the treatment, fruit pulp temperatures of 70 °F (or above) are recommended to minimize water temperature recovery time and the overall time fruit are immersed in heated water. Fruit quality of treated lychees with initial pulp temperatures below 68 °F has not been studied.

TABLE 5-2-1: Determine Dip Time Based on Origin of Fruit

If the origin of the fruit is:	And the shape of the fruit is:	And the weight is (grams):	Then dip:
Puerto Rico, U.S. Virgin Islands, or West Indies (excluding Aruba, Bonaire, Curacao, Margarita, Tortuga or Trinidad and Tobago)	Flat, elongated varieties[1]	Up to 400 grams	65 minutes
		400 to 570 grams	75 minutes
	Rounded varieties[2]	Up to 500 grams	75 minutes
		500 to 700 grams	90 minutes

1 Such as 'Frances,' 'Carrot,' 'Zill,' 'Ataulfo,' 'Carabao,' and 'Irwin.'

2 Such as 'Tommy Atkins,' 'Kent,' 'Hayden,' and 'Keitt.', and Manila

TABLE 5-2-2: Determine Dip Time Based on Origin of Fruit

If the origin of the fruit is:	And the shape of the fruit is:	And the weight is (grams):	Then dip:
Mexico or Central America (north of and including Costa Rica)	Flat, elongated varieties[1]	Up to 375 grams	65 minutes
		375 to 570 grams	75 minutes
	Rounded varieties[2]	Up to 500 grams	75 minutes
		500 to 700 grams	90 minutes

1 Such as 'Frances,' 'Carrot,' 'Zill,' 'Ataulfo,' 'Carabao,' and 'Irwin.'

2 Such as 'Tommy Atkins,' 'Kent,' 'Hayden,' and 'Keitt.', and Manila

TABLE 5-2-3: Determine Dip Time Based on Origin of Fruit

If the origin of the fruit is:	And the shape of the fruit is:	And the weight is (grams):	Then dip:
Panama, South America or West Indies islands of Aruba, Bonaire, Curacao, Margarita, Tortuga, or Trinidad and Tobago	Flat, elongated varieties[1]	Up to 375 grams	65 minutes
		375 to 570 grams	75 minutes
	Rounded varieties[2]	Up to 425 grams	75 minutes
		425 to 650 grams	90 minutes

1 Such as 'Frances,' 'Carrot,' 'Zill,' 'Ataulfo,' 'Carabao,' and 'Irwin.'

2 Such as 'Tommy Atkins,' 'Kent,' 'Hayden,' and 'Keitt.', and Manila

T102-b Passion Fruit from Chile

Pest: *Brevipalpus chilensis* (Chilean false spider mite of grapes)

Treatment: **T102-b-2** Soapy water and wax

1. Immerse fruit for 20 seconds in soapy water bath of one part soap solution (such as Deterfruit) to 3,000 parts water.
2. Follow the soapy bath with a pressure shower rinse to remove all the soapy excess.

3. Immerse fruit for 20 seconds in an undiluted wax coating (such as Johnson's Wax Primafresh 31 Kosher fruit coating). The wax coating should cover the entire surface of the fruit.

Important

At the port of entry, the PPQ officer should check to make sure the wax coating covers the entire surface of the fruit.

T103— High Temperature Forced Air

T103-a-1 Citrus from Mexico and infested areas in the United States

Pest: *Anastrepha* spp.

Treatment: T103-a-1 High-temperature forced air treatment

1. Prepare fruit for treatment
   A. Place temperature probes into the center of the largest fruit in the load.

      The number and placement of temperature probes must be approved by the Oxford Plant Protection Center before Plant Protection and Quarantine (PPQ) can authorize treatment. The Oxford Plant Protection Center grants approval of treatment equipment and facilities through a chamber certification procedure.

      Only fruit varieties listed in **Table 5-2-4** are authorized by PPQ for shipment with treatment T103-a-1. Also, this fruit cannot exceed the maximum commercial size for varieties listed in **Table 5-2-4**. Fruit can be sized before or after the heat treatment. The largest fruit in a load can be identified by either:

      - sizing all fruit prior to heating and selecting the largest size class among the load or
      - acquiring fruit of the largest permitted maximum commercial size class.

   B. Place the fruit containing the temperature probes inside the hot air chamber at chamber locations specified by PPQ during the chamber certification.

TABLE 5-2-4: Maximum Commercial Size of Citrus Varieties Authorized by PPQ for Shipment with Treatment T103-a-1

Citrus Variety[1]	Standard Count[2]	Size Container (in bu.)	Max. Weight/fruit (g)	oz.	Max. Diameter (inches)
Navel Orange	100	1 2/5	450	15.9	3 13/16
Orange (other than Navel Orange)	100	1 2/5	468	16.4	3 13/16
Tangerine	120	4/5	245	8.6	Not specified
Grapefruit	70	1 2/5	536	18.8	4 5/16

1 For tolerance data and research citations, contact USDA-ARS Subtropical Research Center or the Oxford Plant Protection Laboratory.

2 Standard pack count is an index based on the approximate number of fruit of uniform diameter that fit into a 1 2/5-bushel container (4/5-bushel container in the case of tangerines).

2. Increase fruit temperature within specifications

A. Increase the fruit center temperature to 44 °C (111.2 °F) within 90 minutes or more (minimum approach time is 90 minutes) for all temperature probes.

B. Keep the fruit center temperature at 44 °C (111.2 °F) or hotter for 100 minutes.

Fruit center temperatures must be recorded every two (2) minutes for the duration of the treatment.

The total treatment time will vary with the time required to reach 44 °C (111.2 °F).

EXAMPLE: The center temperature of fruit located in the coolest location inside a forced air chamber required 112 minutes to reach 44 °C. Therefore, the total treatment time for this particular fruit load would be 112 + 100 = 212 minutes

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EXAMPLE: The center temperature of fruit located in the coolest location inside a forced air chamber required 80 minutes to reach 44 °C. Therefore, 10 minutes would be added (80+10=90) and the total treatment time for this particular fruit load would be 90 + 100 = 190 minutes

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3. Reduce fruit temperature

Reduce the temperature of the fruit after the treatment is completed. (Hydrocooling after treatment is optional.)

T103-b-1 Citrus from Hawaii

Pest: ***Ceratitis capitata*** (Mediterranean fruit fly), ***Bactrocera dorsalis*** (Oriental fruit fly), and ***B. cucurbitae*** (melon fly)

Treatment: **T103-b-1** High temperature forced air

The steps must occur in order:

1. Insert temperature probes (sensors) into the centers of the largest fruits. The number of sensors must be approved in advance. Sensors shall be physically placed in various parts of the load so that high, middle, and low areas are all represented.

> NOTICE: Do not begin treatment until the fruit center temperatures reach ambient temperature.

2. Load fruits (placed in open trays, bulk bins, or ventilated boxes) into the treatment chamber, and attach sensors to the recorder monitor. Set the monitor to record the temperatures from all sensors at least once every 5 minutes.
3. Heat the fruit in the chamber using forced hot air until the fruit center temperature (all sensors) reaches at least 117.0 °F (47.2 °C).

- The temperature of the forced air used to heat the fruit in the chamber may be constant (single air temperature) or increased (from ambient air temperature) in a series of two or more steps, or ramped over the treatment duration.
- Treatment time will vary, but in every case it must be at least 4 hours or more in duration. The total time leading up to the end-point temperature (117.0 °F or 47.2 °C) is counted as part of the treatment.

4. Cool the fruit by forced air or hydrocooling. Cooling can be initiated immediately after all sensors reach at least 117.0 °F (47.2 °C).

> NOTICE: Tolerance of Citrus to Treatment— Users of this treatment for citrus should test the specific cultivar to determine how well it will tolerate the required heat treatment. Of all citrus species tested to date, grapefruit showed the highest tolerance to this treatment. The tolerance of citrus treated in excess of 7 hours has not been determined. Although the method of cooling fruit after treatment is optional, research indicated that forced air cooling using ambient air temperature produced the least fruit injury.

T103-c-1

Mango from Mexico

Pest: *Anastrepha ludens* (Mexican fruit fly), *Anastrepha obliqua* (West Indian fruit fly), and *Anastrepha serpentina* (black fruit fly)

Treatment: **T103-c-1** Single-stage high temperature forced air

Size of fruit–standard sizes 8 to 14

Weight of fruit–Must not exceed 1 1/2 pounds. (700 grams)

The steps must occur in order:

1. Probe at least three of the largest mangoes at the seed's surface. Insert probes into the thickest portion of the fruit's pulp.
2. Record temperatures at least once every two minutes until the treatment is concluded.
3. Introduce air heated to 122 °F (50 °C) in the chamber.
4. Conclude the treatment once the temperature at the seed's surface (based on the coolest part of the fruit) reaches 118 °F (48 °C).

NOTICE — Treatment time will vary depending on the size of the fruit and the number of boxes treated.

T103-d-1

Mountain Papaya from Chile

Pest: ***Ceratitis capitata*** (Mediterranean fruit fly), ***Bactrocera dorsalis*** (Oriental fruit fly), and ***B. cucurbitae*** (melon fly)

Treatment: **T103-d-1** High temperature forced air

The steps must occur in order:

1. Insert temperature probes (sensors) into the centers of the largest fruits. The number of sensors must be approved in advance. Sensors shall be physically placed in various parts of the load so that high, middle, and low areas are all represented.

NOTICE — Do not begin treatment until the fruit center temperatures reach ambient temperature.

2. Load fruits (placed in open trays, bulk bins, or ventilated boxes) into the treatment chamber and attach sensors to the recorder monitor. Set the monitor to record the temperatures from all sensors at least once every 5 minutes.

3. Heat the fruit in the chamber using forced hot air until the fruit center temperature (all sensors) reaches at least 117.0 °F (47.2 °C).

- The temperature of the forced air used to heat the fruit in the chamber may be constant (single air temperature) or increased (from ambient air temperature) in a series of two or more steps, or ramped over the treatment duration.
- Treatment time will vary, but in every case it must be at least 4 hours or more in duration. The total time leading up to the end-point temperature (117.0 °F or 47.2 °C) is counted as part of the treatment.

4. Cool the fruit by forced air or hydrocooling. Cooling can be initiated immediately after all sensors reach at least 117.0 °F (47.2 °C).

NOTICE — If papayas are hydrocooled with water lower than 54.5 °F (12.5 °C), the fruit may be damaged.

NOTICE — Tolerance of Papayas to Treatment— To enable the papayas to tolerate the treatment, the fruit may first have to be conditioned. Such conditioning is the responsibility of the shipper and at the shipper's risk.

T103-d-2

Papaya from Belize and Hawaii

Pest: ***Ceratitis capitata*** (Mediterranean fruit fly), ***Bactrocera dorsalis*** (Oriental fruit fly), and ***B. cucurbitae*** (melon fly)

Treatment: **T103-d-2** High temperature forced air

The steps must occur in order:

1. Insert temperature probes (sensors) into the centers of the largest fruits. The number of sensors must be approved in advance. Sensors shall be physically placed in various parts of the load so that high, middle, and low areas are all represented.

NOTICE — Do not begin treatment until the fruit center temperatures reach ambient temperature.

2. Load fruits (placed in open trays, bulk bins, or ventilated boxes) into the treatment chamber and attach sensors to the recorder monitor. Set the monitor to record the temperatures from all sensors at least once every 5 minutes.
3. Heat the fruit in the chamber using forced hot air until the fruit center temperature (all sensors) reaches at least 117.0 °F (47.2 °C).

- The temperature of the forced air used to heat the fruit in the chamber may be constant (single air temperature) or increased (from ambient air temperature) in a series of two or more steps, or ramped over the treatment duration.
- Treatment time will vary, but in every case it must be at least 4 hours or more in duration. The total time leading up to the end-point temperature (117.0 °F or 47.2 °C) is counted as part of the treatment.

4. Cool the fruit by forced air or hydrocooling. Cooling can be initiated immediately after all sensors reach at least 117.0 °F (47.2 °C).

NOTICE

If papayas are hydrocooled with water lower than 54.5 °F (12.5 °C), the fruit may be damaged.

NOTICE

Tolerance of Papayas to Treatment— To enable the papayas to tolerate the treatment, the fruit may first have to be conditioned. Such conditioning is the responsibility of the shipper and at the shipper's risk.

T104— Pest Specific/Host Variable

For the treatments that follow, never exceed the labeled or Section 18 dosage and time for the specific commodity at the given temperature. Moreover, the specific commodity being treated determines if the schedule is a labeled treatment or one authorized under a Section 18 exemption. For example, oranges cannot be treated for hitchhikers using T104A-1 at 40-49 °F because this schedule requires 4 pounds of methyl bromide/1,000 ft^3. Whereas, the methyl bromide "Q" label allows a maximum of only 3 pounds at this temperature range. Therefore, the oranges would have to be raised to at least 50 °F before fumigation could be initiated because at 50 °F a dosage of only 3 pounds/1,000 ft^3 is required.

Although the following treatments are pest specific, the treatment schedule for the associated host will determine if and when a pest specific treatment can be used. Always check the schedule for the host before selecting the proper treatment schedule. Also, consult the methyl bromide labeling brochure, and do not exceed the restrictions on dosage and exposure time.

T104-a-1 Various Commodities*

Pest: Hitchhikers and surface pests such as: thrips, aphids, scale insects, leafminers, spider mites, lygaeid bugs, ants, earwigs, and surface feeding caterpillars.

Treatment: **T104-a-1** MB at NAP– tarpaulin or chamber

Temperature	Dosage Rate ($lb/1,000\ ft^3$)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	1.5 lbs	19	14
70-79 °F	2 lbs	26	19
60-69 °F	2.5 lbs	32	24
50-59 °F	3 lbs	38	29
40-49 °F	4 lbs	48	38

Important

* To comply with dosage restrictions imposed by the methyl bromide "Q" label, the following fruits and vegetables may be fumigated only at the following temperatures (the items bolded are under FIFRA Section 18 Exemption. Check with Environmental Services in Riverdale, MD or Oxford Plant Protection Laboratory for the current exemption date:

40 °F or above (maximum dosage, 4 pounds/1,000 ft^3):
Apple, apricot, asparagus, **banana**, **blackberry**, cabbage, **cactus fruit (tuna)**, cantaloupe, **celery**, chayote, cherry, chestnut, **chicory**, cipolini, cucumber, **Dasheen**, **endive**, fava bean (dried), **fresh herbs**[1], grape, honeydew melon, **kiwi**, **leafy vegetables**, muskmelon, nectarine, peach, **pear**, pepper, pineapple, **plantain**, plum, **raspberry**, **snow peas**[2], squash (summer, winter), stone fruit, sweet potato, watermelon, yam.

50 °F or above (maximum dosage, 3 pounds/1,000 ft^3):
Bean, beet, carrot, citron (ethrog), coconut, Corn-on-the-cob (sweet corn), eggplant, garlic, **ginger**, grapefruit, green pod vegetables, horseradish, Jerusalem artichoke, kumquat, lemon, lime, okra, onion, orange, parsnip, pea, potato, radish, rutabaga, salsify, strawberry, sugar beet, tangelo, tangerine, tomato, turnip.

60 °F or above (maximum dosage, 2.5 pounds/1,000 ft^3):
Pimento, pumpkin, zucchini.

70 °F or above (maximum dosage, 2 pounds/1,000 ft^3):
Avocado, blueberry, cocoa bean.

1 Fresh herbs must be on the approved list shown under T101-n-2, Herbs, fresh (includes all fresh plant parts except seeds).

2 Snow peas may be damaged at dosages higher than 3 lbs./1000 cu. ft., and the dosage used in the 40 °F or above temperature range, 4 lbs./1000 cu. ft., should be used only at the importer's request.

T104-a-2

Various Commodities*

Pest: Mealybugs (Pseudococcidae)

Treatment: **T104-a-2** MB at NAP– tarpaulin or chamber

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At:	
		0.5 hr	2 hrs
80 °F or above	2.5 lbs	32	24
70-79 °F	3 lbs	38	29
60-69 °F	4 lbs	48	38

Important

* To comply with dosage restrictions imposed by the methyl bromide "Q" label, the following fruits and vegetables may be fumigated only at the following temperatures (the items bolded are under Section 18 Exemption. FIFRA Section 18 Exemption. Check with Environmental Services in Riverdale, MD or Oxford Plant Protection Laboratory for the current exemption date:

60 °F or above (maximum dosage, 4 pounds/1,000 ft^3):
Apple, apricot, asparagus, **banana**, **blackberry**, cabbage, cantaloupe, **celery**, chayote, cherry, chestnut, **chicory**, cipolini, cucumber, **dasheen**, **endive**, fava bean (dried), grape, **fresh herbs**[1], honeydew melon, **kiwi**, **leafy vegetables**, **lychee (litchi)**, muskmelon, nectarine, peach, **pear**, pepper, pineapple, **plantain**, plum, **raspberry**, **snow peas**, squash (summer, winter), stone fruit, sweet potato, watermelon.

70 °F or above (maximum dosage, 3 pounds/1,000 ft^3):
Bean, beet, carrot, citron (ethrog), coconut, corn-on-the-cob (sweet corn), eggplant, garlic, **ginger root**, grapefruit, green pod vegetables, horseradish, Jerusalem artichoke, kumquat, lemon, lime, okra, onion, orange, parsnip, potato, radish, rutabaga, salsify, scallion, shallot, strawberry, sugar beet, tangelo, tangerine, tomato, turnip.

80 °F or above (maximum dosage, 2.5 pounds/1,000 ft^3):
Peppers, pimento, pumpkin, zucchini.

1 Fresh herbs must be on the approved list shown under T101-n-2, Herbs, fresh (Includes all fresh plant parts except seeds).

T105— Irradiation

T105-a-4 **Abiu from Hawaii**

Pest: ***Ceratatis capitata*** (Mediterranean fruit fly), ***Bactrocera cucurbitae*** (melon fly), and ***Bactrocera dorsalis*** (Oriental fruit fly)

Treatment: Use T105-a-1 Irradiation

T105-a-5 **Atemoya from Hawaii**

Pest: ***Ceratatis capitata*** (Mediterranean fruit fly), ***Bactrocera cucurbitae*** (melon fly), and ***Bactrocera dorsalis*** (Oriental fruit fly)

Treatment: Use T105-a-1 Irradiation

T105-a-2 **Carambola from Hawaii**

Pest: ***Ceratatis capitata*** (Mediterranean fruit fly), ***Bactrocera cucurbitae*** (melon fly), and ***Bactrocera dorsalis*** (Oriental fruit fly)

Treatment: Use T105-a-1 Irradiation

T105-a-6 **Longan from Hawaii**

Pest: ***Ceratatis capitata*** (Mediterranean fruit fly), ***Bactrocera cucurbitae*** (melon fly), and ***Bactrocera dorsalis*** (Oriental fruit fly)

Treatment: Use T105-a-1 Irradiation

T105-a-3 **Lychee (Litchi) fruit from Hawaii**

Pest: ***Ceratatis capitata*** (Mediterranean fruit fly), ***Bactrocera cucurbitae*** (melon fly), and ***Bactrocera dorsalis*** (Oriental fruit fly)

Treatment: Use T105-a-1 Irradiation

T105-a-1 **Papaya from Hawaii**

Pest: ***Ceratatis capitata*** (Mediterranean fruit fly), ***Bactrocera cucurbitae*** (melon fly), and ***Bactrocera dorsalis*** (Oriental fruit fly)

Treatment: T105-a-1 Irradiation

The minimum absorbed dose of gamma irradiation shall be 250 Gray (25 krad), but shall not exceed the 1000-Gray (100 krad) limit imposed by Food and Drug Administration regulations. Documentation of the dosage shall accompany the shipment.

Dose mapping is required for each commodity and/or size. Different configurations, packaging, and/or mixed commodities should also be dose mapped.

Important

The treatment shall be conducted only on Hawaiian-grown produce, and treated at an approved facility, which may be located in any of the following
— Hawaii
— In areas of the mainland United States that do **not** support fruit files (any State except AL, AZ, CA, FL, GA, KY, LA, MS, NV, NM, NC, SC, TN, TX, or VA)

NOTICE

The papayas, carambolas and lychees destined for irradiation treatment may arrive in the same container, but must not be commingled with other fruits and vegetables.

These shipments must be accompanied by a Limited Permit (PPQ Form 530).

Important

For specific details on dosimetry, consult the American Society for Testing and Materials (ASTM) publication, E 1261-94, **Standard Guide for Selection and Calibration of Dosimetry Systems for Radiation Processing.**

(Publication available from: ASTM, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania, USA 19428-2959).

T105-a-7

Rambutan from Hawaii

Pest: ***Ceratatis capitata*** (Mediterranean fruit fly), ***Bactrocera cucurbitae*** (melon fly), and ***Bactrocera dorsalis*** (Oriental fruit fly)

Treatment: Use T105-a-1 Irradiation

T105-a-8

Sapodilla from Hawaii

Pest: ***Ceratatis capitata*** (Mediterranean fruit fly), ***Bactrocera cucurbitae*** (melon fly), and ***Bactrocera dorsalis*** (Oriental fruit fly)

Treatment: Use T105-a-1 Irradiation

T106— Vapor Heat

T106-b-1 Bell Pepper

Pest: *Ceratitis capitata* (Mediterranean fruit fly), *Bactrocera dorsalis* (Oriental fruit fly), and *Bactrocera cucurbitae* (melon fly)

Treatment: T106-b-1 Vapor heat

1. Raise temperature of article by saturated water vapor at 112 °F until approximate center of fruit reaches 112 °F within a time period designated by the PPQ officer.
2. Hold fruit temperature at 112 °F for 8.75 hours, then cool immediately.

Pretreatment conditioning is optional and is the responsibility of the shipper. Treatment is required for shipments from Hawaii.

> **Important**
> Commodities should be exposed at 112 °F to determine tolerance to the treatment before commercial shipments are attempted.

T106-a-1 Clementine from Mexico

Pest: *Anastrepha* spp. (includes Mexican fruit fly, *A. ludens*)

Treatment: T106-a-1 Vapor heat

Raise fruit pulp temperatures gradually to 110 °F until center of fruit reaches that temperature in 8 hours. Hold temperature at 110 °F for 6 hours.

T106-a-1-1 Clementine or Orange from Mexico (Alternate treatment)

Treatment: T106-a-1-1 Vapor heat

Raise fruit pulp temperature to 110 °F until the center of fruit reaches that temperature in 6 hours. Hold temperature at 110 °F for 4 hours. During the initial raising of fruit temperature, the first 2 hours should raise the temperature rapidly, the increase over the next 4 hours should be gradual.

T106-b-2 Eggplant

Pest: *Ceratitis capitata* (Mediterranean fruit fly), *Bactrocera dorsalis* (Oriental fruit fly), and *Bactrocera cucurbitae* (melon fly)

Treatment: T106-b-2 Vapor heat

1. Raise temperature of article by saturated water vapor at 112 °F until approximate center of fruit reaches 112 °F within a time period designated by the PPQ officer.
2. Hold fruit temperature at 112 °F for 8.75 hours, then cool immediately.

Pretreatment conditioning is optional and is the responsibility of the shipper. Treatment is required for shipments from Hawaii.

Important

Commodities should be exposed at 112 °F to determine tolerance to the treatment before commercial shipments are attempted.

T106-a-2

Grapefruit from Mexico

Pest: *Anastrepha* spp. (includes Mexican fruit fly, *A. ludens*)

Treatment: T106-a-2 Vapor heat

Raise fruit pulp temperatures gradually to 110 °F until center of fruit reaches that temperature in 8 hours. Hold temperature at 110 °F for 6 hours.

T106-a-3

Mango* from Mexico

Pest: *Anastrepha* spp. (includes Mexican fruit fly, *A. ludens*)

Treatment: T106-a-3 Vapor heat

Raise fruit pulp temperatures gradually to 110 °F until center of fruit reaches that temperature in 8 hours. Hold temperature at 110 °F for 6 hours.

Important

* Manila variety only.

T106-d-1

Mango from the Philippines (the island of Guimaras only)

Pest: *Bactrocera* spp. (includes fruit f lies *Bactrocera occipitalis* and *Bactrocera philippinesis*)

Treatment: T106-d-1 Vapor heat

1. Size the fruit before the treatment. Place temperature probes in the center of the large fruits.

2. Raise the temperature of the fruit by saturated water vapor to 114.8°F (46°C), measured at the center of the fruit, in a minimum of 4 hours. (The temperature of the saturated water vapor should be 117.5°F (47.5°C)
3. Hold fruit temperature at 114.8°F (46°C) for 10 minutes.

Important

During the run-up time, temperature should be recorded from each pulp sensor once every 5 minutes. During the 10 minute holding time, temperature should be recorded from each pulp sensor every minute.

During the last hour of treatment, which includes the 10 minute holding time, the relative humidity must be maintained at 90 percent of higher.

T106-d

Mango from Taiwan*

Pest: *Bactrocera dorsalis* (Oriental fruit fly)

Treatment: **T106-d** Vapor heat

1. Size the fruit before the treatment. Place temperature probes in the center of the large fruits.
2. Raise the temperature of the fruit by saturated water vapor at 117.5°F until the pulp temperature near the seed reaches 115.7°F.
3. Hold pulp temperature at 115.7 °F or above for 30 minutes, then cool immediately.

T106-b-3

Mountain Papaya

Pest: *Ceratitis capitata* (Mediterranean fruit fly), *Bactrocera dorsalis* (Oriental fruit fly), and *Bactrocera cucurbitae* (fly)

Treatment: T106-b-3 Vapor heat

1. Raise temperature of article by saturated water vapor at 112 °F until approximate center of fruit reaches 112 °F within a time period designated by the PPQ officer.
2. Hold fruit temperature at 112 °F for 8.75 hours, then cool immediately.

Pretreatment conditioning is optional and is the responsibility of the shipper. Treatment is required for shipments from Hawaii.

NOTICE

This schedule is not being used at the present time because Taiwan has no preclearance program in place.

Important

Commodities should be exposed at 112 °F to determine tolerance to the treatment before commercial shipments are attempted.

T106-a-4

Orange from Mexico

Pest: *Anastrepha* spp. (includes Mexican fruit fly, *A. ludens*)

Treatment: T106-a-4 Vapor heat

Raise fruit pulp temperatures gradually to 110 °F until center of fruit reaches that temperature in 8 hours. Hold temperature at 110 °F for 6 hours.

T106-b-4

Papaya

Pest: *Ceratitis capitata* (Mediterranean fruit fly), *Bactrocera dorsalis* (Oriental fruit fly), and *Bactrocera cucurbitae* (melon fly)

Treatment: T106-b-4 Vapor heat

1. Raise temperature of article by saturated water vapor at 112 °F until approximate center of fruit reaches 112 °F within a time period designated by the PPQ officer.
2. Hold fruit temperature at 112 °F for 8.75 hours, then cool immediately.

Pretreatment conditioning is optional and is the responsibility of the shipper. Treatment is required for shipments from Hawaii.

Important

Commodities should be exposed at 112 °F to determine tolerance to the treatment before commercial shipments are attempted.

T106-c

Papaya

Pest: *Ceratitis capitata* (Mediterranean fruit fly), *Bactrocera dorsalis* (Oriental fruit fly), and *Bactrocera cucurbitae* (melon fly)

Treatment: T106-c Vapor heat (Quick run-up)

1. Raise temperature of article until approximate center of fruit reaches 117 ° F (47.2 ° C) in a time period of 4 hours or more. During the last hour of treatment, the relative humidity (RH) in the chamber must be maintained at 90 per cent or greater.

Important

Pretreatment conditioning is optional and is the responsibility of the shipper. Treatment is required for shipments from Hawaii.

T106-b-5

Pineapple (other than smooth Cayenne)

Pest: *Ceratitis capitata* (Mediterranean fruit fly), *Bactrocera dorsalis* (Oriental fruit fly), and *Bactrocera cucurbitae* (melon fly)

Treatment: T106-b-5 Vapor heat

1. Raise temperature of article by saturated water vapor at 112 °F until approximate center of fruit reaches 112 °F within a time period designated by the PPQ officer.
2. Hold fruit temperature at 112 °F for 8.75 hours, then cool immediately.

Pretreatment conditioning is optional and is the responsibility of the shipper. Treatment is required for shipments from Hawaii.

Important

Commodities should be exposed at 112 °F to determine tolerance to the treatment before commercial shipments are attempted.

T106-b-6

Squash

Pest: *Ceratitis capitata* (Mediterranean fruit fly), *Bactrocera dorsalis* (Oriental fruit fly), and *Bactrocera cucurbitae* (melon fly)

Treatment: T106-b-6 Vapor heat

1. Raise temperature of article by saturated water vapor at 112 °F until approximate center of fruit reaches 112 °F within a time period designated by the PPQ officer.
2. Hold fruit temperature at 112 °F for 8.75 hours, then cool immediately.

Pretreatment conditioning is optional and is the responsibility of the shipper. Treatment is required for shipments from Hawaii.

Important

Commodities should be exposed at 112 °F to determine tolerance to the treatment before commercial shipments are attempted.

T106-b-7 Tomato

Pest: *Ceratitis capitata* (Mediterranean fruit fly), *Bactrocera dorsalis* (Oriental fruit fly), and *Bactrocera cucurbitae* (melon fly)

Treatment: T106-b-7 Vapor heat

1. Raise temperature of article by saturated water vapor at 112 °F until approximate center of fruit reaches 112 °F within a time period designated by the PPQ officer.
2. Hold fruit temperature at 112 °F for 8.75 hours, then cool immediately.

Pretreatment conditioning is optional and is the responsibility of the shipper. Treatment is required for shipments from Hawaii.

Important

Commodities should be exposed at 112 °F to determine tolerance to the treatment before commercial shipments are attempted.

T106-b-8 Zucchini

Pest: *Ceratitis capitata* (Mediterranean fruit fly), *Bactrocera dorsalis* (Oriental fruit fly), and *Bactrocera cucurbitae* (melon fly)

Treatment: T106-b-8 Vapor heat

1. Raise temperature of article by saturated water vapor at 112 °F until approximate center of fruit reaches 112 °F within a time period designated by the PPQ officer.
2. Hold fruit temperature at 112 °F for 8.75 hours, then cool immediately.

Pretreatment conditioning is optional and is the responsibility of the shipper. Treatment is required for shipments from Hawaii.

Important

Commodities should be exposed at 112 °F to determine tolerance to the treatment before commercial shipments are attempted.

T107— Cold Treatment

Pulp of the Fruit

The pulp of the fruit must be at or below the indicated temperature at time of beginning treatment for all cold treatments.

Fruits for Which Cold Treatment Is Authorized

The following table is a list of countries that are authorized by PPQ to use cold treatment for the control of specific pests associated with shipments of fruit. The cold treatment schedule that must be used for specific commodities from the listed countries is listed before the commodities. These cold treatment schedules follow **Table 5-2-5 on page-5-2-67**, and indicate the specific pests for which they are designed to control. The asterisks located after the listed fruits indicate that fumigation with methyl bromide is also required. Check the Index to the Schedules for those additional treatments.

Treatment upon arrival may be accomplished at authorized ports as named in the permits; treatment in transit may be authorized for specifically equipped and approved vessels or containers and from approved countries, for entry at ports named in the permits. Intransit cold treatment authorization must be preceded by a visit to the country of origin by a PPQ official to explain loading, inspection, and certification procedures to designated certifying officials of country of origin. Refrigerated compartments on carrying vessels and cold storage warehouse must have prior certification by PPQ. Authorization of cold treatments from countries with direct sailing time less than the number of days prescribed for intransit refrigeration treatment must be contingent on importer understanding that prescribed intransit refrigeration period must be met before arrival of vessel at the approved U.S. port.

Gaps in the cold treatment data print-out for pulp sensors and air sensors shall be allowed or disallowed on a case-by-case basis, taking into account the number of gaps, the length of each gap, and the temperatures before and after. Air temperatures may occasionally exceed treatment temperatures during defrost cycles; however, fruit temperatures should not rise appreciably during this time. During non-defrost times, the temperatures of the air sensors should never exceed the maximum allowable treatment temperature.

TABLE 5-2-5: Countries and fruits for which Cold Treatment is Authorized

Albania	T107-a ethrog
Algeria	T107-a clementine, ethrog, grape*, grapefruit, pear, plum, orange
Argentina	T107-c apple, apricot, cherry, grape**, nectarine, peach, pear, plum, pomegranate, quince, T107-c kiwi
Armenia	T107-a grape*
Australia	T107-d apple, grapefruit, kiwi, orange, pear, tangerine
Austria	T107-a grape*
Azerbaijan	T107-a grape*
Belarus	T107-a grape*
Belize	T107-b ethrog, grapefruit, orange, tangerine, T107-c carambola
Bermuda	T107-a grapefruit, orange
Bolivia	T107-c grapefruit, orange
Bosnia	T107-a ethrog
Brazil	T107-c apple, grape
Bulgaria	T107-a grape*
Chile	T107-a apple, apricot**, cherry, grape**, kiwi, loquats, mountain papaya, nectarine**, peach, pear, plum**, plumcot, quince
China	T107-f Ya pear, T107-h lychee
Colombia	T107-b clementine, grapefruit, orange, plum, pomegranate
Colombia	T107-c grape
Corsica	T107-a ethrog
Costa Rica	T107-b clementine, ethrog, grapefruit, orange
Croatia	T107-a ethrog
Cyprus	T107-a clementine, ethrog, grape*, grapefruit
Dominican Republic	T107-c grape
Ecuador	T107-c apple, clementine, grapefruit
Ecuador	T107-a ethrog
Egypt	T107-a grape*, orange, pear
El Salvador	T107-b clementine, ethrog, grapefruit, orange
Estonia	T107-a grape*
France	T107-a apple, ethrog, grape*, kiwi, pear
Georgia	T107-a grape*
Germany	T107-a grape*
Greece	T107-a clementine, ethrog, grape*, kiwi, pomegranate, orange
Guatemala	T107-b clementine, ethrog, grapefruit, orange, plum
Guyana	T107-c apple, orange
Haiti	T107-c apricot, pomegranate
Hawaii	T107-f carambola, T107-a avocado***, T107-i, Hawaiian Salsa
Honduras	T107-b clementine, ethrog, grapefruit, orange
Hungary	T107-a apple, grape*
India	T107-f grape

TABLE 5-2-5: Countries and fruits for which Cold Treatment is Authorized

Israel	T107-a clementine, apple, apricot, ethrog, grape*, grapefruit, lychee, loquat, nectarine, orange, peach, pear, persimmon, plum, pomegranate, pummelo
Italy	T107-a clementine, apple, ethrog, grape*, grapefruit, kiwi, orange, pear, persimmon
Jordan	T107-a apple, persimmon
Kazakhstan	T107-a grape*
Kyrgyzstan	T107-a grape*
Latvia	T107-a grape*
Lebanon	T107-a apple
Libya	T107-a ethrog, grape*
Lithuania	T107-a grape*
Luxembourg	T107-a grape*
Macedonia	T107-a ethrog
Mexico	T107-b apple, apricot, cherry, grapefruit, orange, peach, plum, tangerine, T107-c carambola
Moldova	T107-a grape*
Morocco	T107-a clementine, apricot, ethrog, grape*, grapefruit, orange, peach, pear, plum
Nicaragua	T107-b clementine, ethrog, grapefruit, orange
Panama	T107-b clementine, ethrog, grapefruit, orange
Peru	T107-c grape
Portugal	T107-a ethrog, grape*, pear, apple
Russia	T107-a grape*
South Africa	T107-a apple, grape, pear, T107-e nectarine, peach, plum, citrus (fruit from Western Cape Province)
Spain	T107-a apple, clementine, ethrog, grape*, grapefruit, loquat, orange, pear, T107-a kiwi
Suriname	T107-c clementine, grapefruit, orange
Switzerland	T107-a grape*
Syria	T107-a ethrog, grape*
Taiwan	T107-f carambola, T107-h lychee, longans
Tajikistan	T107-a grape*

TABLE 5-2-5: Countries and fruits for which Cold Treatment is Authorized

Trinidad and Tobago	T107-c clementine, grapefruit, orange
Tunisia	T107-a clementine, ethrog, grape*, grapefruit, orange, peach, pear, plum
Turkey	T107-a ethrog, grape*, orange
Turkmenistan	T107-a grape*
Ukraine	T107-a grape*
Uruguay	T107-c apple, grape, nectarine, peach, pear, plum
U.S.A.	T107-a citrus, T107-b citron, litchi, longan, persimmon, white zapote (interstate movement)
Uzbekistan	T107-a grape*
Venezuela	T107-c clementine, grape, grapefruit, orange
Zimbabwe	T107-a apple, kiwi, pear, T107-e apricot, peach, plum, nectarine

* T101-h-2 also required.

** T101-i-2 also required.

Important

For Hawaiian-grown avocados, research has shown that, during the process of cold treatment (T107-a), a single transient heat spike of no greater than 39.6 °F and no longer than 2 hours, during or after 6 days of cold treatment, does not affect the efficacy of the treatment. However, in the absence of supporting research, such a tolerance for heat spikes shall not be extended to other fruits.

Important

Pretreatment conditioning (heat shock or 100.4 °F for 10 to 12 hours) is optional and is the responsibility of the shipper. The pretreatment conditioning, which may improve fruit quality, is described in HortScence 29 (10): 1166-1168. 1994. and 30(5): 1052-1053 (1995)

Important

Cold treatment in *break-bulk* vessels must be initiated by an APHIS officer when shipments are from Chile, Greece, Italy, and Taiwan. However, cold treatment in *containers* may be initiated by treatment technicians from these countries only because they have been trained to initiate cold treatments for containers and not break-bulk vessels.

T107-a

Commodity and Specific Origin are listed in Table 5.2.4

Pest: *Ceratitis capitata* (Mediterranean fruit fly) or *Eutetranychus orientalis* (Oriental citrus mite)

Treatment: T107-a Cold treatment

Temperature	Exposure Period
32 °F or below	10 days
33 °F or below	11 days
34 °F or below	12 days
35 °F or below	14 days
36 °F or below	16 days

T107-b

Commodity and Specific Origin are listed in Table 5.2.4

Pest: *Anastrepha ludens* (Mexican fruit fly)

Treatment: **T107-b** Cold treatment

Temperature	Exposure Period
33 °F or below	18 days
34 °F or below	20 days
35 °F or below	22 days

T107-c

Commodity and Specific Origin are listed in Table 5.2.4

Pest: Species of *Anastrepha* (other than *Anastrepha ludens)* or *Ceratitis capitata* (Mediterranean fruit fly)

Treatment: **T107-c** Cold treatment

Temperature	Exposure Period
32 °F or below	11 days
33 °F or below	13 days
34 °F or below	15 days
35 °F or below	17 days

T107-d

Commodity and Specific Origin are listed in Table 5.2.4

Pest: *Bactrocera tryoni* (Queensland fruit fly)

Treatment: **T107-d** Cold treatment

Temperature	Exposure Period
32 °F or below	13 days
33 °F or below	14 days
34 °F or below	18 days
35 °F or below	20 days
36 °F or below	22 days

T107-e

Commodity and Specific Origin are listed in Table 5.2.4

Pest: *Cryptophlebia leucotreta* (false codling moth) and *Pterandrus rosa* (Natal fruit fly)

Treatment: **T107-e** Cold treatment

Temperature	Exposure Period
31 °F or below*	22 days

* The treatment shall not commence until all sensors are reading 31.0 F or below. If the temperature exceeds 31.5°F, the treatment shall be extended one-third of a day for each day or part of a day the temperature is above 31.5°F. If the exposure period is extended, the temperature during the extension period must be 34° F or below. If the temperature exceeds 34°F at any time, the treatment is nullified. Also, some freeze damage to the fruit may occur if the pulp temperature is allowed to drop below approximately 29.5°F (This varies with the commodity.)

T107-f

Commodity and Specific Origin are listed in Table 5.2.4

Pest: *Bactrocera cucurbitae* (Melon fly), *Bactrocera dorsalis* (Oriental fruit fly), *Ceratitis capitata* (Mediterranean fruit fly), and *Eutetranychus orientalis*

Treatment: **T107-f** Cold treatment

Temperature	Exposure Period
32 °F or below	10 days
33 °F or below	11 days
34 °F or below	12 days
35 °F or below	14 days

T107-g

Commodity and Specific Origin are listed in Table 5.2.4

Pest: *Curculio caryae* (Pecan weevil)

Treatment: **T107-g** Cold treatment

Temperature	Exposure Period
32 °F or below	7 days

T107-h

Commodity and Specific Origin are listed in Table 5.2.4

Pest: *Bactrocera dorsalis* (Oriental fruit fly), *Bactrocera curcubitae* (melon fly) and *Conopomorpha sinensis* (lychee fruit borer)

Treatment: **T107-h** Cold treatment

Temperature	Exposure Period
33.4°F or below	13 days
33.8 °F or below	15 days
34.5 °F or below	18 days

T107-i

Commodity and Specific Origin are listed in Table 5.2.4

Pest: *Ceratitus caitata* (Mediterranean fruit fly) and *Bactrocera relativeness* (Solanaceous fruit fly)

Treatment: **T107-h** Cold treatment

Temperature	Exposure Period
30.2 °F or below	6 days
41 °F or below	10 days

T108— Fumigation Plus Refrigeration of Fruits

Fruits for Which Fumigation Followed by Cold Treatment Is Authorized

The following table is a list of countries and States that are authorized by PPQ to use fumigation followed by cold treatment for the control of specific pests associated with shipments of fruit. Check the Index to the Schedules for those additional treatments.

TABLE 5-2-6: Countries, States, and Associated Fruit for Which T108 Is Authorized

Albania	ethrog (citron)
Algeria	ethrog, grape, pear, plum
Armenia	grape
Australia	apple, grape, pear
Austria	grape
Azerbaijan	grape
Belarus	grape
Bosnia	ethrog
Bulgaria	grape
Chile[1]	apple, apricot, cherry, grape, nectarine, peach, pear, plum, plumcot, quince
Corsica	ethrog
Croatia	ethrog
Cyprus	ethrog, grape
Ecuador	ethrog
Egypt	grape, pear
Estonia	grape
France	apple, ethrog, grape, pear
Georgia	grape
Germany	grape
Greece[1]	clementine, ethrog, grape
Hawaii	avocado
Hungary	apple, grape

TABLE 5-2-6: Countries, States, and Associated Fruit for Which T108 is Authorized

Israel	ethrog, grape, plum
Italy[1]	apple, ethrog, grape, peach, pear
Kazakhstan	grape
Kyrgyzstan	grape
Latvia	grape
Libya	ethrog, grape
Lithuania	grape
Luxembourg	grape
Macedonia	ethrog
Moldova	grape
Morocco	ethrog, grape, peach, pear, plum, apricot
Portugal	ethrog, grape
Russia	grape
Slovenia	ethrog
Spain	apple, ethrog, grape, pear
Switzerland	grape
Syria	ethrog, grape
Tajikistan	grape
Tunisia	ethrog, grape, peach, pear
Turkey	ethrog
Turkmenistan	grape
Ukraine	grape
U.S.A.	citrus* (interstate movement)
Uzbekistan	grape
Yugoslavia	ethrog

1 Cold treatment in break-bulk vessels must be initiated by an APHIS officer when shipments are from Chile, Greece, Italy, and Taiwan. However, cold treatment in containers may be initiated by treatment technicians from these countries only because they have been trained to initiate cold treatments for containers and not break-bulk vessels

NOTICE

* Some varieties of fruit may be injured by exposure to MB. Importers should be encouraged to treat small samples of fruit to determine tolerance levels before shipping commercial quantities. The USDA is not liable for damages caused by quarantine.

T108-a

Commodity and Specific Origin are listed in Table 5.2.5

Pest: *Bactrocera cucurbitae* (melon fly), *Bactrocera dorsalis* (Oriental fruit fly), *Bactrocera tryoni* (Queensland fruit fly), *Brevipalpus chiliensis* (false red mite), *Ceratitis capitata* (Mediterranean fruit fly), *Lobesia botrana* (grapevine moth)

Treatment: **T108-a**
Three alternative schedules based upon the fumigation exposure time

NOTICE

Some varieties of fruit may be injured by the 3 hour exposure. Importers should be encouraged to test treat small quantities to determine tolerance before shipping commercial quantities.

Important

Time lapse between fumigation and start of cooling not to exceed 24 hours.

T108-a-1

Commodity and Specific Origin are listed in Table 5-2-5

Treatment: **T108-a-1** (2 hour schedule) MB at NAP—tarpaulin or chamber followed by cold treatment

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At: 0.5 hr	2 hrs
70 °F or above	2 lbs	25	18
Followed by cold treatment			

Refrigeration Temperature	Exposure Period
33 to 37 °F	4 days
OR 38 to 47 °F	11 days

T108-a-2

Commodity and Specific Origin are listed in Table 5-2-5

Treatment: **T108-a-2** (2.5 hour schedule) MB at NAP—tarpaulin or chamber followed by cold treatment

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At: 0.5 hr	2 hrs	2.5 hrs
70 °F or above	2 lbs	25	18	18
Followed by cold treatment				

Refrigeration	
Temperature	Exposure Period
34 to 40 °F	4 days
OR 41 to 47 °F	6 days
OR 48 to 56 °F	10 days

T108-a-3

Commodity and Specific Origin are listed in Table 5-2-5

Treatment: **T108**-a-3 (3 hour schedule) MB at NAP—tarpaulin or chamber followed by cold treatment

Temperature	Dosage Rate (lb/1,000 ft³)	Minimum Concentration Readings (ounces) At: 0.5 hr	2 hrs*	2.5 hrs	3 hrs
70 °F or above	2 lbs	25	18	18	17
Followed by cold treatment					

Refrigeration	
Temperature	Exposure Period
43 °F to 47 °F	3 days
OR 48 °F to 56 °F	6 days

* Some commodities may exceed label dosage. Check the label of the gas being used before you start a fumigation.

T108-b

Apple, grape, and pear

Pest: *Austrotortrix* spp. and *Epiphyas* spp. (light brown apple moth complex), *Bactrocera tryoni* (Queensland fruit fly), *Ceratitis capitata* (Mediterranean fruit fly) and other fruit flies

Treatment: T108-b MB at NAP—tarpaulin or chamber followed by cold treatment

Temperature	Dosage Rate (lb/1,000 ft³)	Minimum Concentration Readings (ounces) At: 0.5 hr	2 hrs*
50 °F or above	1.5 lbs	23	20
40-49 °F	2 lbs	30	25
Followed by cold treatment			

Temperature	Exposure Period
33 ° or below	21 days
OR 48 ° to 56 °F	6 days

NOTICE

Alternate treatment for fumigation plus refrigeration of fruits (T108) is refrigeration plus fumigation of fruits (T109).

Important

Load not to exceed 80 percent of chamber capacity. Time lapse between fumigation and start of cooling not to exceed 24 hours.

T109— Cold Treatment Plus Fumigation of Fruits

T109-d-1 Apple, grape, and pear from Australia

Pest: *Austrotortrix* spp. and *Epiphyas* spp. (light brown apple moth complex), *Bactrocera tryoni* (Queensland fruit fly), *Ceratitis capitata* (Mediterranean fruit fly) and other fruit flies

Treatment: T109-d-1 Cold treatment followed by MB at NAP—tarpaulin or chamber

Temperature	Exposure Period
33 °F or below	21 days
Followed by MB at NAP— tarpaulin or chamber	

Temperature	Dosage Rate (lb/1,000 ft^3)	Minimum Concentration Readings (ounces) At: 0.5 hr	2 hrs
70 °F or above	2 lbs	30	25
60-69 °F	2.5 lbs	36	28
40-59 °F	3 lbs	44	36

Alternate treatment for *Austrotortrix* and *Epiphyas* is fumigation plus refrigeration (**T108-b**).

Alternate treatment for grapes from Australia as a fruit fly precautionary treatment for *Bactrocera tryoni* and *Ceratitis capitata* is fumigation plus refrigeration (**T108-a** and **T108-b**).

NOTICE

Load not to exceed 80 percent of capacity.

T109a

Apple ('Fuji' apple from Japan and Korea)

Pest: *Carposina niponensis* (peach fruit moth), *Conogethes punctiferalis* (yellow peach moth), *Tetranychus viennensis* (fruit tree spider mite), *Tetranychus kanzawai* (Kanzawa mite)

Two alternative schedules based on type of container

T109-a-1

Treatment: **T109-a-1** (apples in plastic field bins at maximum load factor 50 percent or less) Cold treatment followed by MB at NAP—tarpaulin or chamber

Temperature	Exposure Period
34 °F or below	40 days
Followed by MB at NAP— tarpaulin or chamber	

Temperature	Dosage Rate (lb/1,000 ft³)	Minimum Concentration Readings (ounces) At: 0.5 hr	2 hrs
50 °F or above	3 lbs	44	36

T109-a-2

Treatment: **T109-a-2** (apples in only cardboard cartons at maximum load factor 40 percent or less) Cold treatment followed by MB at NAP– tarpaulin or chamber

Temperature	Exposure Period
34 °F or below	40 days
Followed by MB at NAP— tarpaulin or chamber	

Temperature	Dosage Rate (lb/1,000 ft³)	Minimum Concentration Readings (ounces) At: 0.5 hr	2 hrs
59 °F or above	2 lbs 6 oz	35	29

T110— Quick Freeze

Treatment: T110 Quick Freeze

1. Initially, lower the commodity's temperature to 0 °F or below.
2. Hold the commodity's temperature at 20 °F or below for at least 48 hours.

The commodity may be transported during the 48-hour treatment period, but at no time may the commodity's temperature rise above 20 °F prior to release.

All fruits and vegetables* are enterable from all foreign countries after receiving the above treatment in accordance with 7CFR 319.56-2c. Also, interstate movement of all fruits and vegetables from offshore areas of the United States (except mango from Hawaii) is authorized in the frozen state after being quick frozen.

Important

Quick freeze may damage fruit.

Of course, freezing will ruin the market quality of most fresh fruits and vegetables, except for thick-skinned items such as durian and coconut. Generally, the Quick Freeze treatment is used on fruits and vegetables that will be processed into another form (e.g., for puree, juice, or mashed vegetables). Also, this treatment is considered an acceptable method of destroying most commodities in lieu of returning them to the country of origin, with the exceptions listed below.

Important

Exceptions*— **Avocados with seeds are prohibited from South America, Central America, or Mexico; however, avocados from certain areas of Mexico during specific times may enter the United States. **Citrus with peel** is prohibited from Afghanistan, Andaman Islands, Argentina, Bangladesh, Brazil, Caroline Islands, Cambodia, China (People's Republic of), Comoros, Côte d'Ivoire, Fiji Islands, Home Island in Cocos (keeling) Islands, Hong Kong, India, Indonesia, Japan and adjacent islands, Korea, Laos, Madagascar, Malaysia, Maldives, Mauritius, Mozambique, Myanmar, Nepal, Oman, Pakistan, Papua New Guinea, Paraguay, Philippines, Reunion Islands, Rodrigues Islands, Ryukyu Islands, Saudi Arabia, Seychelles, Sri Lanka, Taiwan, Thailand, Thursday Island, United Arab Emirates, Uruguay, Vietnam, Yemen, or Zaire. **Mangoes with seeds** are prohibited from Barbados, Dominica, French Guiana, Guadeloupe, Martinique, St. Lucia, and all countries outside of North, Central, and South America and their adjacent islands (which include the Caribbean Islands and Bermuda). **Black currants** are enterable only to areas specified in the import permit. **Corn-on-the-cob** is prohibited from Albania, Algeria, Bosnia and Hercegovina, Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Lebanon, Libya, Malta, Macadonia, Morocco, Sardinia, Slovenia, Spain, Syria, Tunisia, Turkey, or Yugoslavia (Serbia and Montenegro).